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WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

EDITORIAL AND BUSINESS OFFICES

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New York, N. Y.

NEW JOURNAL

This is the first issue of the Journal printed in a larger size. The Meetings and Papers Committee are planning to make further improvement, from time to time, as the finances of the Society permit. Constructive suggestions are invited.

BOUND VOLUMES

Bound volumes of the Journal for the year 1930 are now available in attractive imitation black leather covers. This volume contains a wealth of information on all phases of welding. Price per copy $5.00. Subject and Authors' Indices permitting easy reference are included. A few bound volumes for the years 1924-to-date, are still available at $5.00 per copy.

By an arrangement with Russell-Rutter Company, 461 Eighth Avenue, New York, N. Y., bookbinders for the Society, members of the Society may have their individual issues of the 1930 Journal bound in permanent book form with imitation leather covers by sending copies of the twelve issues *to that Company*.

A charge of $1.50 will be billed by the American Welding Society.

This arrangement expires March 1, 1931.

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JOURNAL OF THE AMERICAN WELDING SOCIETY

Vol. X JANUARY, 1931 No. 1

Research Inspection Tour

A group of some fifteen university professors recently participated in an inspection tour arranged under the auspices of the Fundamental Research Committee of the American Bureau of Welding.

The purpose of this committee is to stimulate fundamental research work in the welding field among the various universities. To this end, the committee has compiled a list of research problems and, when called upon, assists in the formulation of any problem undertaken for study and in supplying specimens as may be needed made up under conditions required by the particular laboratory.

A number of professors interested indicated to the officers of the committee a desire to see, first hand, the applications of the various welding processes in order that they may be able to use this knowledge in their classes and in order that they may have a better understanding of the problems undertaken for study.

A three-day inspection trip and conference were arranged. The party assembled on the morning of Dec. 29 in the Engineering Societies Building at 9.30 a. m. Transportation and lunch were provided through the courtesy of the Metal and Thermit Corp. and the Air Reduction Company, whose plants were visited in the morning and afternoon, respectively. A variety of applications of thermit welding were demonstrated, as were also the latest developments in machine cutting, machine welding and hand welding with the torch.

The party was then transported to the Grand Central Station and boarded a train for Schenectady. Early the next morning the group were taken to the plant of the General Electric Company, divided into groups of three, and guides provided. A wide variety of applications of welding were shown varying from small articles to huge dynamo electric machinery entirely fabricated by welding. All processes of welding and cutting find applications in the works of this company. Some of the latest applications of resistance welding were also shown.

Lunch was provided in one of the dining rooms and later the party assembled in the auditorium of the research laboratory, where several lectures, properly illustrated, on the application of welding and needs of research, were given. The party left in the evening for New York.

On Wednesday morning transportation was provided to the Union Carbide and Carbon Research Laboratories, where, again, demonstrations and lectures were given on the latest developments of gas welding and cutting, including high-speed pipe welding and bronze welding. Lunch was provided and in the afternoon lectures were given on various applications of welding and the testing of welds.

The party included the following professors:

G. E. Beggs, Princeton University.
E. Haertlein, Harvard University.
Otto Henry, the Polytechnic Institute.
W. F. Hess, Rensselaer Polytechnic Institute.
A. Hoadley, Union College.
G. B. Karelitz, Columbia University.
W. B. Kouwenhoven, Johns Hopkins University.
P. G. Laurson, Yale University.
P. M. Lincoln, Cornell University.
J. T. Norton, Massachusetts Institute of Technology.
M. Sayre, Union College.
J. H. Smith, University of Pittsburgh.
A. E. Wells, Cornell University.

This inspection trip was made possible by contributions from the following:

Air Reduction Sales Company.
American Chain Company.
Page Steel & Wire Co.
General Electric Company.
Babcock & Wilcox Co.
Lincoln Electric Company.
F. T. Llewellyn.
Metal & Thermit Corp.
Union Carbide & Carbon Corp.

Welding Research in U. S. S. R.

(Extract from Bulletins published by the Kieff Polytechnical Institute, 1930.)

Extensive tests are being carried on at Kieff, U. S. S. R., in Kieff Experimental Bureau.

This work was undertaken, since welding in that country acquires very great importance in the erection of new industrial plants and other engineering constructions.

Although the engineers and professors entrusted with this work are thoroughly familiar with the results and the technique adopted in other countries, still in order to apply them effectively to the local conditions, they carry out an extensive research in their own technical colleges and experimental bureaus.

In order to compare the arc welded structures with the riveted ones, the large size beams and girders are being tested both with the static and dynamic loads. The direct comparison of the welded and riveted structures of the identical dimensions gives immediately the practical information on the behavior of such structures. These tests include the measurements of load distribution, deflections and examination of the welded and riveted joints after the application of each load up to the failure of the sample. Extensive metallographic investigations are also being carried out to determine the structure of the deposited metal and the influence of the heat on the parent metal.

The conclusions as reported in several technical pamphlets may be briefly described as follows:

The welded beams possess higher resistance than the riveted beams to dynamic loads. They carry the dynamic loads just as well as static loads. On the average, the welded beams are stronger than riveted beams of the identical design by 3 per cent for static loads and by 12 per cent for dynamic loads.

Annual Meeting Heating and Ventilating Engineers

An invitation has been extended to members of the American Welding Society to attend the 37th annual meeting of the American Society of Heating and Ventilating Engineers at the William Penn Hotel, Pittsburgh, Pa., on Jan. 26 to 29.

The program includes a welding paper entitled "Welded Piping for Building Heating Systems" by F. G. Outcalt, at the Wednesday morning session, Jan. 28.

A Communication

New York, N. Y., Dec. 12, 1930.

Mr. W. Spraragen, Editor, JOURNAL OF AMERICAN WELDING SOCIETY, 33 West Thirty-ninth Street, New York, N. Y.

Dear Sir—

I noticed that Professor McKibben's paper, "American Methods of Welding Structural Steel," in the November issue of the JOURNAL, describes somewhat in detail my patented method of reinforcing structural members under load obtaining the required initial stress.

The strengthening of a New York Central Railroad overhead bridge in the Bronx, New York, between East 157th Street and East 159th Street, is a contract which we recently completed for the New York Central Railroad.

I would very much appreciate your mention in the next issue of the JOURNAL of the fact that this is a patented method.

Very truly yours,

The Leake & Nelson Company,

(Signed) A. G. Leake,
President.

Testing Group to Hold Regional Meeting

The second regional meeting of the American Society for Testing Materials is to be held at Hotel William Penn, Pittsburgh, March 18, at which time a comprehensive symposium on welding will be presented. The spring group committee meeting of the society also will be held in Pittsburgh during the week in which the regional meeting is held.

The technical program for the meeting will include the following: "The Quality of Materials for Welding," by F. N. Speller and C. R. Textor, National Tube Co., Lorain, Ohio; "Technical Examples of Modern Welding Practice," by A. M. Candy, general engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., a contribution from the American Welding Society; and "The Inspection and Testing of Welded Products," as related to fatigue and impact tests for welded connections, X-ray testing, magnetic testing, stethoscope examination of welded products, and practical inspection of finished welded products.—From American Welding Society, Pittsburgh Sec.

SECTION ACTIVITIES

BOSTON

At the December meeting, held on Friday the 19th, R. A. Wolff, president of Wolff & Munier, Inc., presented a paper on panel heating. He described the fabricating by welding and the installing of the equipment in the new British Embassy building in Washington. This installation is the first to be made in this country of heating by the panel method. Motion pictures were shown in conjunction with Mr. Wolff's talk. The attendance at this meeting was about 100.

On Jan. 28 the Boston Section will hold a joint meeting with the Boston Society of Civil Engineers in Chipman Hall, Tremont Temple, at 7:00 p. m. The meeting will be devoted to three speakers discussing the planning, specifying, supervising and welding of the new fourteen-story Edison Building. The speakers will be J. T. Whitney, president, The Whitney Engineering Co., formerly Whidden-Beekman Engineering Co., Boston; J. L. Faden, industrial heating engineer, The Edison Electric Illuminating Co. of Boston, and A. G. Leake, president, Leake & Nelson Co., Bridgeport. Slides and motion pictures will be used during the discussion.

At the meeting on Feb. 20 J. F. Lincoln, president of the Lincoln Electric Co., will discuss the fleetweld or shielded arc process. Demonstration welds will be made to illustrate his talk.

CHICAGO

Among the most successful meetings of the Chicago Section were the regular sessions of December and January. Eighty-two members and guests were on hand for the December dinner preceding the meeting in the Palmer House Hotel. The meeting proper followed at 7:30, Dec. 12, when three phases of non-destructive testing of welds were discussed and demonstrated. Fred Outcalt, Linde Air Products Co. described the possibilities of the stethoscope in determining the qualities of a weld. A shell was provided in which welds of four predetermined qualities were included. E. W. Page, General Electric X-ray Corporation had previously made X-ray pictures of these four sections which were thrown on the screen and discussed by Mr. Page. He was followed by C. E. Swift, Westinghouse Electric Mfg. Company, who talked on the possibilities of magnetographic weld testing. He also gave a practical demonstration of how magnetographs are made, using the welded shell for his work. Over one hundred and seventy-five were on hand for the presentation of these discussions.

The January meeting, on the evening of the ninth, was fortunate in hearing an illustrated paper presented by E. P. Bestler of Raymond Bros. Impact Pulverizer Company, whose subject was "Production Welding of Sheet Metal Products." Mr. Bestler indicated how a wide variety of complicated products was made possible only by welding.

Another feature of the evening was a continuation of the tests conducted at the December meeting. During the interim magnetographs of the four weld sections of the specimen shell were made after which tensile coupons were prepared. These latter were pulled in a portable tensile testing machine, at the meeting, and the results posted so that direct comparisons between the three methods of testing could be made.

A regular feature of the Chicago Section meetings this year is the dinner served at 6:00 o'clock in dining room No. 12 of the Palmer House Hotel. Everyone is cordially invited to attend both the meeting proper and the dinner which precedes it. Regular meetings are the first Friday of the month.

CLEVELAND

The Cleveland Section held a very successful meeting on Thursday evening, Dec. 11 at the Cleveland Engineering Society rooms in Carnegie Hall. Mr. Gurley, editor of Welding, spoke on the Oxy-Acetylene Process in the Welding Industry. The paper was illustrated by slides and Mr. Gurley covered his subject thoroughly. After the paper had been presented there was a good discussion from the floor. The Cleveland Section feels that their first two meetings for this year were exceptionally successful.

DETROIT

The following is the program for coming meetings of the Detroit Section:

January 26 — "Structural Steel Welding."—Joseph T. Matte of Albert Kahn, Inc., Consulting Engineers, Detroit.

March 24—"Resistance Welding." —P. W. Fassler, Fisher Body Co., Detroit.

April 28 — "Electric Arc Welding." Representative of Westinghouse Elec. & Mfg. Co., Pittsburgh.

It is anticipated that the January meeting on structural steel welding will create much enthusiasm inasmuch as the Detroit City Council is now considering a new building code which will permit welding on steel structures.

A nominating committee will be appointed in January to select the new officers to be voted upon at the April meeting.

LOS ANGELES

The December meeting of the Los Angeles Section was in the nature of a visit to the Southern Pacific R. R. Shops, Los Angeles. Mr. O. B. Schwenky made the arrangement on

(CONTINUED ON PAGE 49)

Proposed Specifications for Fusion Welding of Unfired Pressure Vessels

✦ Based on Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers as Referred to in Par. U-23 Revised. This paper will be presented at a joint meeting of the New York Sections of the American Welding Society and the American Society of Mechanical Engineers.

IN a recent revision of Par. U-23 of the Code for Unfired Pressure Vessels which is now effective, the following statement is made:

All joints in vessels covered by this Code and of any dimensions may be fusion welded provided that in addition to meeting the requirements for material and design, they will conform to specifications now being prepared for inclusion in this Code, based on those which have been published under the heading, Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers.

In addition to the specifications referred to, certain revisions are proposed to make the rules in Par. U-23 more widely applicable, and it is intended to further extend the scope of the rules covering vessels which may be fusion welded without being stress relieved.

The Committee is considering amplifying the Code so as to make it apply to vessels operated at temperatures of over 600 deg. fahr., and the inclusion of the allowable working stresses for higher temperatures. The Committee is also considering the classification of pressure vessels and should a classification be adopted, these specifications are primarily intended to cover the class of vessels demanding the highest type of construction.

The following proposed revision and specifications for embodiment in the Code for Unfired Pressure Vessels, which are based on those proposed for power boilers published in the March 1930 issue of the JOURNAL OF THE A. W. S., are submitted for criticisms and comments from anyone interested. Where additional requirements are given in these Specifications over those for power boilers, they will be considered for inclusion in the Specifications for Drums or shells of Power Boilers. Suggestions on the broadening of the rules covering vessels which need not be stress relieved after welding will also be welcomed by the Boiler Code Committee. Discussion and suggestions should be mailed to the Secretary of the Boiler Code Committee, 29 West 39th Street, New York, N. Y., not later than Jan. 15, 1931, in order that they may be presented to the Committee for consideration.

Par. U-23 Revised

U-23. Pressure vessels may be fabricated by means of fusion welding under the rules given in Pars. U-67 to U-79, provided the fabrication is in accordance with the Recommended Procedure for Fusion Welding of Pressure Vessels given in the Appendix, as follows:

(*a*) All [air] vessels other than those containing noxious liquids or gases when the inside diameter does not exceed 60 in., or the working pressure does not exceed 200 lb. per sq. in., or the temperature does not exceed 250 deg. fahr.

(*b*) Vessels, in which the circumferential joints only may be welded, when the inside diameter does not exceed 72 [48] in., or 96 [72] in., when at least 75 per cent of the load on a flat head is supported by tubes or through stays extending from head to head.

All joints in vessels covered by this Code and of any dimensions may be fusion welded provided that in addition to meeting the requirements for material and design, they will conform to the following specifications, based on those which have been published under the heading, Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers.

Proposed Specifications for Fusion Welding of Unfired Pressure Vessels

1. Pressure vessels covered by this Code of any size and for any working pressure may be fabricated by means of fusion welding, providing materials are used which conform with the specifications in Pars. S-5 to S-17, or S-264 to S-279, of Section II of the Code, and the following requirements are fulfilled:

If, in the development of the art of welding, other materials than those herein described become available, specifications may be submitted for consideration.

2. *Test Plates for Longitudinal Joints.* Two sets of test plates of the dimensions shown in Fig. 2 from steel of the same specifications as the drum plates, prepared

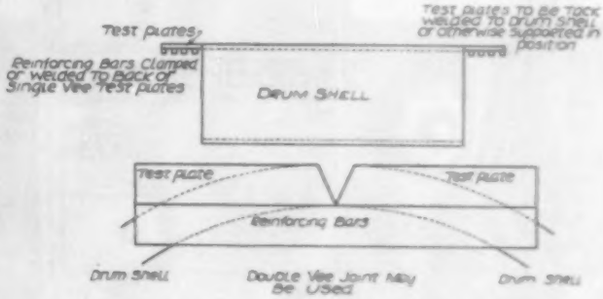

Test plates
Test plates to be Tack welded to drum shell or otherwise supported in position
Reinforcing Bars Clamped or welded to back of Single Vee Test plates
Drum Shell
Test plate
Test plate
Reinforcing Bars
Drum Shell
Double Vee Joint May Be Used
Drum Shell

Fig. 1 Longitudinal Test Plates

for welding, shall be attached to the shell being welded, as in Fig. 1, one set on each end of one longitudinal seam of each drum so that the edges to be welded in the test plates are a continuation of and duplication of the corresponding edges of the longitudinal seam in the shell. Weld metal shall be deposited in the test plates continuously with the weld metal deposited in the longitudinal joint of the shell. As an alternate method, detached test plates may be welded as in the case of circumferential seams covered under Par. 3.

When the joint is of the single-V type, the test plates shall be so supported that the warping due to welding shall not throw the finished test plate out of line by an angle of over 5 deg.

3. *Test Plates for Circumferential Joints.* When test plates are welded for the longitudinal joints, none need be furnished for circumferential joints in the same vessel provided the welding process, procedure, and technique are the same. Where a drum has circumferential joints and no longitudinal joint, two sets of test plates of the same material as the shell shall be welded in the same way as the circumferential joint.

When the joint is of the single-V type, the test plates shall be so supported that warping due to welding shall not throw the finished test plate out of line by an angle of over 5 deg.

4. *Stress Relieving.* The complete welded structure shall be stress relieved. Stress relieving shall be obtained by heating uniformly to at least 1100 deg. fahr. The structure or parts of the structure shall be brought

slowly up to the specified temperature and held at that temperature for a period of at least one hour per inch of thickness, and shall be allowed to cool slowly in a still atmosphere. The test plates shall be subjected to the same stress-relieving operation, preferably by placing within the parent vessel.

The structure shall be stress relieved by any of the following methods:

a. Heating the complete vessel as a unit.

b. Heating a complete section of the vessel (head or course) containing the part or parts to be stress relieved before attachment to other sections of the vessel.

c. In cases where the vessel is stress relieved in sections, stress relieving the final girth joints by heating uniformly a circumferential band having a minimum width of 6 times the plate thickness on each side of the welded seam, in such a manner that the entire band shall be brought up to the temperature and held for the time specified above for stress relieving.

Where the welding has warped the test plates they shall be straightened cold before being stress relieved.

5. *Test Specimens.* The inspector shall select one of the two welded test plates from which the coupons for tension, impact, and bend tests and for specific-gravity determinations shall be removed as shown in Fig. 2.

6. *Tension Tests.* Two types of tension test specimens are required, one of the joint and the other of the weld metal. The tension specimen of the joint shall be transverse to the welded joint, and shall be the full thickness of the welded plate after the outer and inner surfaces of the weld have been machined to a plane surface flush with the plate. When the capacity of the available testing machine does not permit of testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements.

Each tension specimen should fail in the plate, but if failure occurs in the weld metal or along the line of fusion between weld metal and the plate, then the tensile strength shall not be less than the minimum of the specified tensile range of the plate used.

The tension test specimen of the weld metal shall be taken entirely from the deposited weld metal and shall meet the following requirements for tensile strength, elongation, and reduction of area; tensile strength to be at least that of the minimum of the range of the plate which is welded; elongation and reduction of area to be ... (values to be agreed upon later). The dimensions of the specimen shall conform to those given in Fig. 3. However, should this not be possible, the diameter shall be made as large as practicable and the gage length used shall be 4 times the diameter of the specimen.

(The minimum value of 20 per cent of elongation and the omission of the reduction of area requirement are being considered.)

7. *Bend Tests.* The bend-test specimen shall be transverse to the welded joint of the full thickness of the plate and shall be of rectangular cross-section with the width 1½ times the thickness of the plate. When the capacity of the available testing machine does not permit of testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements. The inside and outside surfaces of the weld shall be machined to a plane surface flush with the plate. The edges of this surface shall be rounded to a radius equal to 10 per cent of the thickness of the plate. The specimen shall be bent cold under free bending conditions until the least elongation measured within or across approximately the entire weld on the outside fibers of the bend-test specimen is 30 per cent, with the width of any surface cracks deducted.

8. *Impact Tests.* Three coupons for impact tests shall be taken transverse to the welded joint and prepared so that the cross-section of the specimen through which fracture will occur shall contain: (1) the bottom surface, (2) the middle section, and (3) the top surface of the weld. The notch in the bottom specimen shall be opposite the bottom surface, and in the top

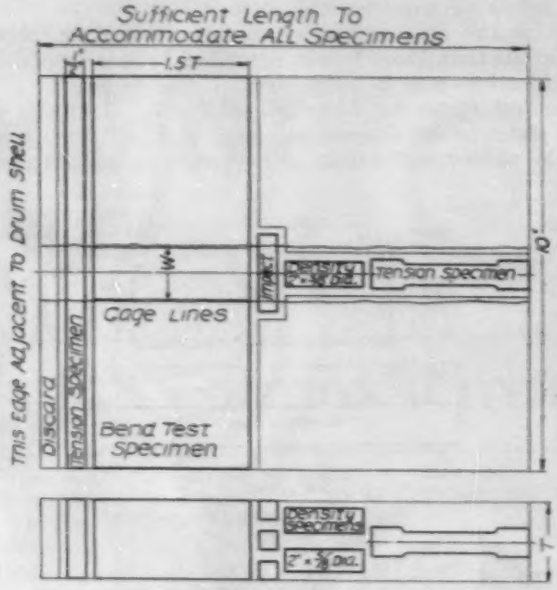


Fig 2
Test Specimens From Longitudinal Welded Test Plates

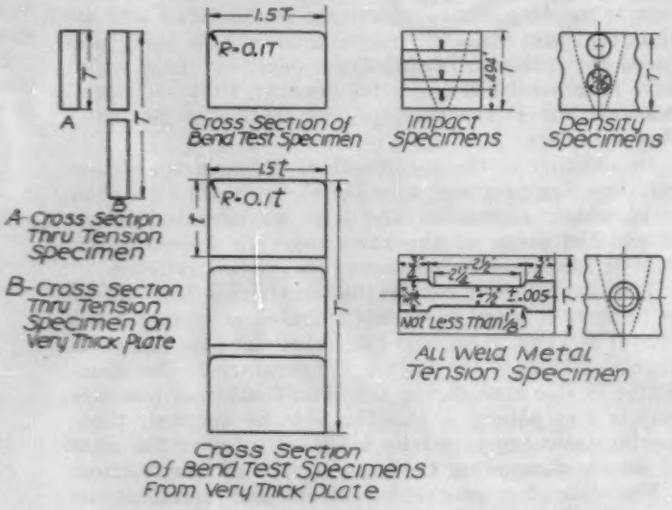
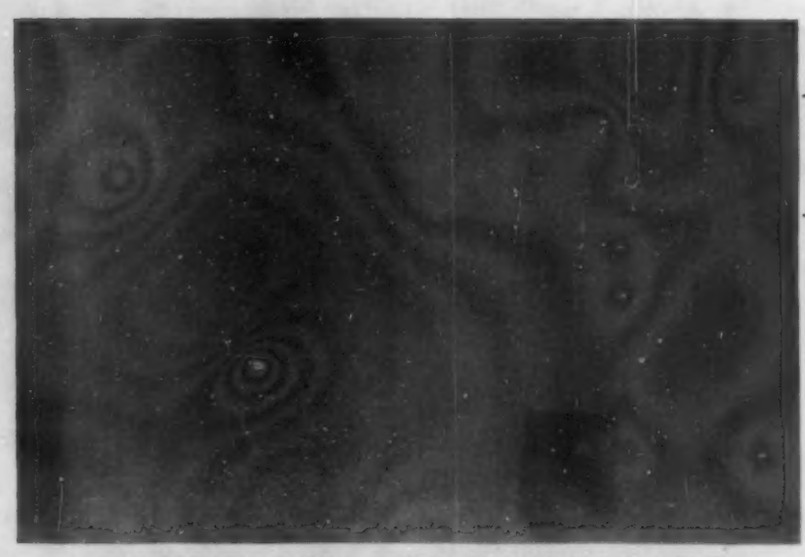


Fig 3
Test Specimens

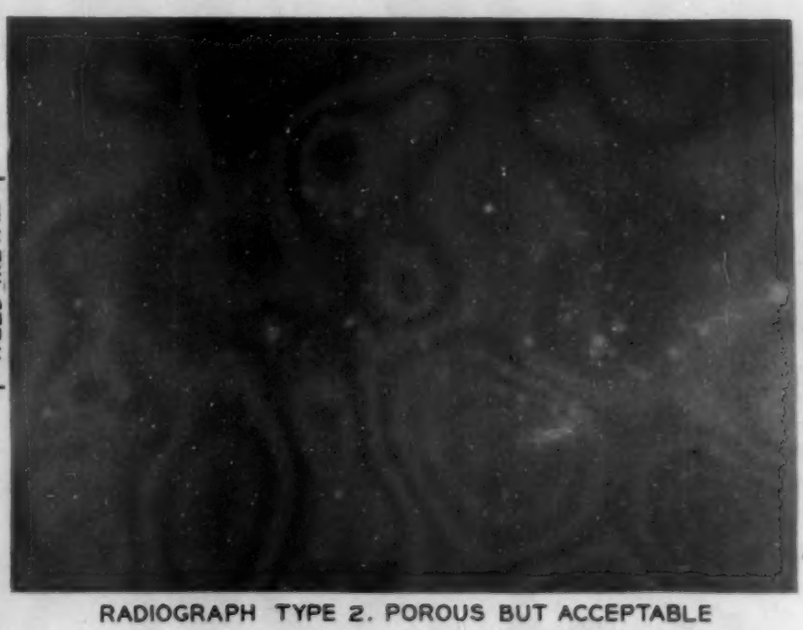


RADIOGRAPH TYPE 1. EXCELLENT OR IDEAL WELD

MACROGRAPH OF TYPICAL SECTION THROUGH WELD OF TYPE 1

RADIOGRAPH TYPE 2. POROUS BUT ACCEPTABLE

MACROGRAPH OF TYPICAL SECTION THROUGH WELD OF TYPE 2

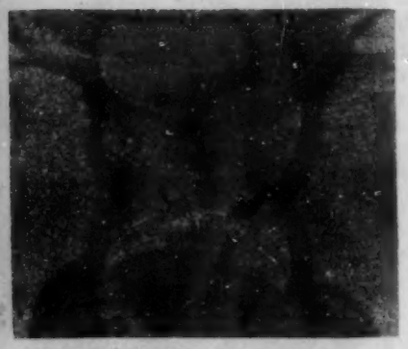


RADIOGRAPH TYPE 2. POROUS BUT ACCEPTABLE

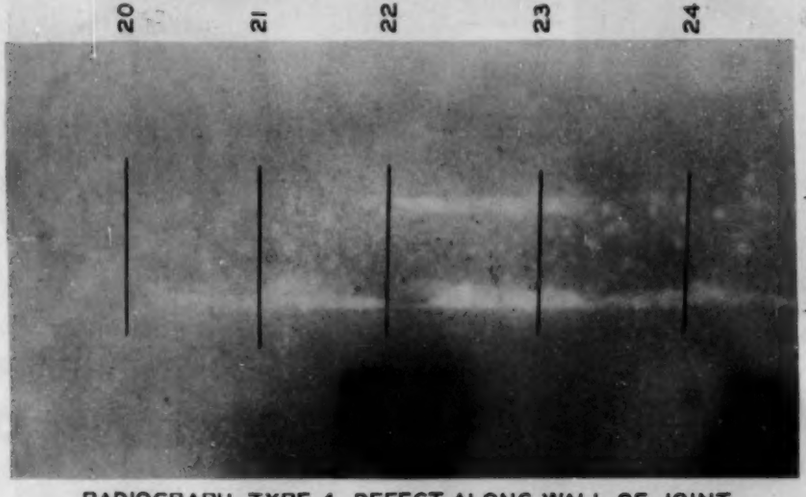
MACROGRAPH OF TYPICAL SECTION THROUGH WELD OF TYPE 2

Radiograph Prints Nos. 1 and 2

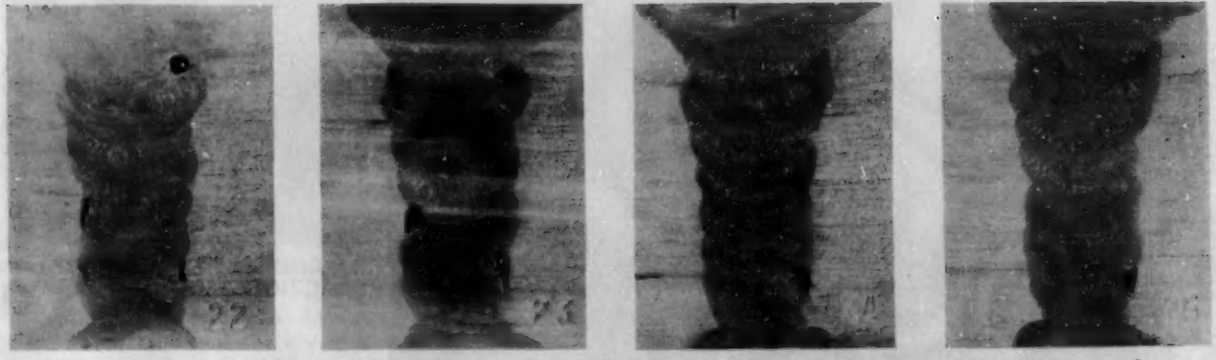
RADIOGRAPH TYPE 3. POROUS AND UNDESIRABLE



MACROGRAPH OF TYPICAL SECTION THROUGH WELD OF TYPE 3



RADIOGRAPH TYPE 4. DEFECT ALONG WALL OF JOINT NOT ACCEPTABLE



MACROGRAPHS OF SECTIONS 21 TO 25 THROUGH WELD IN RADIOGRAPH TYPE 4

Radiograph Prints Nos. 3 and 4

specimen, opposite the top surface. The minimum value of the impact test shall be 20 ft.-lb., standard A. S. S. T. Charpy impact specimen, or the equivalent value of 35 ft.-lb. in the Izod test.

If the plate is not thick enough to obtain three impact specimens in the same vertical section, the specimens shall be obtained from two or three adjacent sections.

9. *Specific Gravity of Weld Metal.* Specimens shall be taken from the weld metal of the joints. These specimens shall, if possible, be 2 in. long and $\frac{5}{8}$ in. in diameter, as shown in Figs. 2 and 3. The minimum specific gravity shall be 7.80.

10. *Retests.* Should any of the tests other than those under Par. 9 fail to meet the requirements by 10 per cent or less, retests shall be allowed on specimens cut from the second welded test plate.

Should any of the tests other than those under Par. 9 fail to meet the requirements by more than 10 per cent, no retests shall be allowed. The retest shall comply with the requirements. For either of the tension retests, two specimens shall be cut from the second test plate and both of these shall meet the requirements.

When there are more than one specimen of the same type and when one or more of the group specimens fail to meet the requirements by 10 per cent or less, the retest shall be made on an entire group of specimens and shall meet the requirements.

Should the specific gravity obtained on the specific-gravity specimen be less than 7.75, no retest shall be allowed. Should the specific gravity lie between 7.75 and 7.80, a retest shall be allowed. The retest shall not show a specific gravity less than 7.80.

11. *Non-Destructive Tests of Vessel.* The main longitudinal and circumferential welded joints of the stress-relieved structure shall be radiographed by a sufficiently powerful X-ray apparatus under a technique which will determine quantitatively the size of a defect with a thickness greater than 2 per cent of the thickness of the base plate. Radiographs shall be obtained for every portion of the main longitudinal and circumferential joints, and photographic prints of the X-ray films submitted to inspector.

Radiographic print No. 1 shows the ideal or desired type of print in which the presence of the welded joint can be detected only with great difficulty. This type represents excellent weld metal with a specific gravity in the neighborhood of 7.80 to 7.85.

Radiographic print No. 2 indicates the presence of some porosity of the weld metal in the joint. This porosity, however, is not excessive and radiographs of this type shall be acceptable.

Radiographic print No. 3 represents a porous condition in the weld metal which is not desirable.

Radiographic print No. 4 represents a serious defect in a welded joint. This defect represents a slag inclusion or cavity extending longitudinally along the wall of the joint. A radiograph of this kind is not acceptable. However, a radiograph showing a defect of this kind in which the length of the defect is less than $1/3T$, where T is the thickness of the joint and where these defects are separated from each other by at least $2T$ of solid weld metal, shall be acceptable, provided they shall not average more than 1 per foot for any one seam.

RADIOGRAPH TYPE 5. DEFECT ALONG WALL OF JOINT—ACCEPTABLE

MACROGRAPH OF SECTION 7

MACROGRAPH OF SECTION 17

Radiograph Print No. 5

A description of the X-ray technique employed shall be summitted with the radiographic prints to the inspector, this record giving:

a. The thickness of the plate.
b. The distance of the film from the rear of the joint.
c. The distance of the film from the source of X-rays.
d. The voltage impressed on the tube.
e. The current flowing through the tube.
f. The time of exposure.
g. The type of film used.
h. The type of intensifying screens.

The locations of the reference markers, the images of which appear on the film, shall be accurately and permanently stamped on the outside surface of the vessel near the weld so that a defect appearing on the X-ray

print may be accurately located in the actual welded joint.

Note: To determine whether the X-ray technique employed is detecting defects of a thickness 2 per cent or greater than the thickness of the base plate, a piece of sheet steel of a thickness equal to 2 per cent of the base plate and containing a hole shall be placed alongside the welded joint so that its image is obtained on the X-ray film but still does not interfere with the image of the welded joint. The image of the hole in the sheet should be obtained on the X-ray film.

12. *Hydrostatic and Hammer Tests.* The vessel shall be subjected to a hydrostatic pressure equal to 1½ times the maximum-allowable working pressure, and while subject to this hydrostatic pressure a thorough hammer or impact test shall be given. This impact test shall consist of striking the sheet on both sides of the welded seam a sharp blow with a hammer which shall be 10 per cent of the weight of 1 sq. ft. of the wall of the vessel and not less than 2 lb., with a handle similar to a blacksmith's striking hammer, the blows to be struck 2 to 3 in. apart along the seam—the blows to be as rapid as a man can conveniently strike a sharp, swinging blow, and as hard as can be struck without bending the metal of the sheet. During the test the shell shall be completely filled with water. The vessel after the test herein specified shall have the pressure raised to 3 times the maximum allowable working pressure, and held there three minutes.

(Raising the pressure to twice instead of 3 times the maximum allowable working pressure after the hammer test, or to a pressure that will produce a stress of 50 per cent of the minimum tensile strength of the specified range of the base metal is being considered.)

13. *Holes.* No holes shall be located in a welded joint. When holes in the plate are located near a welded joint, the minimum distance between the edge of a hole and the edge of a joint shall be equal to the thickness of the plate when the plate thickness is from 1 in. to 2 in. With plates less than 1 in. thick, this minimum distance shall be 1 in. With plates over 2 in. in thickness, the minimum distance shall be 2 in.

(Omission of this restriction is being considered.)

14. *Allowable Working Stress.* When constructed under the above provisions, the maximum unit working stress of a welded joint at right angles to the direction of the joint may be taken as one-fifth of 80 per cent (16 per cent) of the minimum of the specified tensile range of the plate used.

Progress of the Oxy-Acetylene Process in Railroad Shops

By F. HUGGINS

✦ This paper was presented at October 30, 1930 meeting of Portland Section, American Welding Society. Mr. Huggins is an engineer with Air Reduction Company.

BOILER WELDING

MANY railroads used the process in their boiler shop for some time before any attempt at welding was made, it being used for cutting purposes only, and principally on stay bolts. Then some of the more progressive operators began to weld, or try to weld, small cracks in fire boxes. My first experience on this work was perhaps similar to many others. I will relate it to you.

After I had been working with the torch for several weeks, and had made some difficult welds, I thought, the shop superintendent came to me with an order to weld a 4-in. crack in the fire box of a passenger engine which had a four-hour layover in the shop before making her regular run. Four hours to weld 4 in. seemed to be plenty of time, but to make a long story short, about six hours later I came out of the fire box, not leaving a 4-in. crack, but one extending from about the center of the fire box to the mud ring, a distance of about 3½ ft.; and the engine did not go out on her regular run that day, or for several days.

Well, we soon learned that regardless of the length of the crack, we had to make allowance for contraction, and the method then, and still employed, was to heat the metal adjacent to the crack, use a bobbing tool or some other blunt tool, and drive the metal in toward the water line; when the weld was made, it was not built up flush, but sufficient bend left at the corners to take care of the contraction. After successfully mastering small cracks, the next step was small patches, from patches to half side sheets, and now many roads are running all welded fire boxes.

On the coal-fired locomotives, side sheets always begin to deteriorate at the mud ring where the ashes lodge behind the grate bars and the lye from the ashes begins to eat the sheets away. Therefore, it is not necessary to remove the entire box, but only the lower sections. These are called half-side sheets. The old method of repairing these side sheets was a riveted seam or patch bolts. In our first attempt at welding in half-side sheets the sheets were fitted in position, and the mud ring, rivets, and stay bolts all driven before any attempt at welding the seams was made, of course there was no allowance made for contraction, and we had trouble—plenty of it. In fact, we found it impossible to successfully weld sheets thus fitted up.

Our next step was to leave the sheets loose, drop one end and start the weld at the other. The spacing allowance was about ¼ in. to a lineal foot. In other words, on an 8-ft. box the opening at the opposite end from where the welding started, would be 2 in. This method did take care of contraction in most cases, but we found it not so satisfactory because there was no way of knowing the exact spacing to allow. A fast operator would have too much spacing at a ¼ in. per foot, while a slow man would not have sufficient. Therefore, the sheets would nearly always be out of line when the weld was complete. The method then employed, and now used as standard practice, is to make a corrugation, or roll, in the sheets near the weld. When a corrugation is used, the sheets can be put in position, mud ring rivets and the stay bolts, with the exception of the last two rows near the weld, can be driven before the weld is made. The size and type of roll recommended is ¾ in. high in the center, and 4 in. wide, running to nothing at either side. The location is always between the last and next to the last row of stay bolts. A 4-in. corrugation is considered a long one, but long corrugations are desirable on locomotives that work in bad water districts, because a short high corrugation makes a per-

fect mud catcher, preventing the water from coming in contact with the sheet, and thus burning the metal. The reason the corrugation should be located between the stay bolts, is also to prevent the possibility of mud catching on the bolts, resulting in burned sheets.

On the oil-fired locomotives, the sheets begin to deteriorate at the point where the oil enters the fire box, or parallel with the fire door. It is, therefore, not necessary to remove the lower sections of the sheets, but only the center or deteriorated section, and a patch welded in its place. A corrugation similar to the ones recommended for side sheets should be made, running on the outside of the patch. In case the patch is the full length of the fire box a corrugation at the far end seams is not necessary, as the knuckle in the flue and door sheets will sufficiently take care of contraction. On an end weld, only a corrugation for the horizontal seams are necessary.

Machine Shop

I believe we will all agree that one of the most difficult problems in the machine shop, is the welding of locomotive cylinders. It also represents one of the greatest savings to the railroad company. The old method of handling cylinders jobs was, after the break had been veed out, a brick furnace was built up around the entire cylinder, a load of charcoal or some other preheating fuel dumped into the furnace, and when the cylinder was heated a dull cherry red color, a few bricks were removed opposite the break, and all the welder had to do was to stick his torch, and sometimes his hands, into the furnace and weld up the break, using cast iron rod. After the weld was completed, the cylinder was allowed to stay in the furnace until perfectly cool. Now when a cylinder weld is made, the break is chipped out, the metal adjacent to the break cleaned well, either by use of sand blast or grinder, a piece of front-end screening placed in the cylinder and the valve chamber to serve as a grating, the cylinder and valve chamber filled with charcoal, and then wrapped up with roll asbestos, and after it has been preheated sufficiently, the asbestos is removed directly over the break, and bronze used as a filler rod. Considerable time is saved with the use of bronze over cast iron. It is much easier on the operator, and if it is necessary to machine over the weld, it eliminates hard spots which are often found in cast iron welds.

Another major problem in the machine shop, is building up sharp flanges or flat spots on the driving tires. Considerable trouble has been experienced from the effects of these operations, and some roads have discontinued both of them, because of the number of broken tires resulting from built-up flanges or spots, and the Government Inspectors often frown on the operation because of the number of failures throughout the country. Let us see if we can learn the reason why tires break after being worked on with a torch. When the tire is ready to put on the wheel it is expanded by heat and placed on the wheel in an expanded condition. The contraction which takes place as the tire cools, holds it in position on the wheel. Of course, it is always in a tremendous strain, and when a torch is put to work on the tire, cold, an additional strain is set up because of the uneven expansion and contraction, and often the tire breaks in service after it has been welded. To overcome the possibility of breaking the tire, is a simple matter. Before the welding operation is started, place the tire heater on the tire and heat it until it is loose on the wheel. Then weld while the tire is in an expanded condition. It is best to use two torches, but in case one torch is used it is sometimes necessary to use the tire heater two or three times, in order to keep it expanded during the entire operation. If this is done, and the welding operation is properly carried on, there will be no breakage of tires due to building up with the oxy-acetylene torch.

Another operation in the machine shop that has caused considerable trouble in the past, is welding broken spokes or rim in wheel centers, and especially on cast iron centers. Cast iron wheel centers are not used on the modern locomotives today, having been replaced by cast steel, but many locomotives now used in the logging industry still have the cast iron wheels. It is almost impossible to preheat a wheel uniformly while on the axle, because of its upright position, because of the possibility of loosening the wheel on the axle, and of the disastrous effect the heat might have on the appurtenances on the side of the locomtive, so we must forget preheating and find a way to do the job cold. Assume, for example, that we have a cast iron wheel with four broken spokes adjacent to each other, the rim is solid without keys. The first step would be to remove the tire, second, the rim would be split or cut in the center, third, the spokes veed out, fourth, a jack placed between the rim and the wheel center, fifth, the brake on the outside spoke spread or expanded ⅛ of an inch, and bronze used as a filler rod. When the weld on the first spoke is completed, and while still hot, the jack is removed and placed on the other side from where the rim is split, then the second spoke expanded similar to the first. This operation is repeated until all four spokes are welded. After they have cooled, the jack is then placed in a horizontal position between the first two spokes near the rim, and the rim expanded and welded. This we have found is the best method of handling cast iron wheels on locomotives.

Piston Heads. Our first attempt at bronze welding worn heads was very successful as far as the operation was concerned, but the only bronze available at that time was Tobin bronze, which was entirely too soft to stand the wear the heads were subjected to. The result was, the bronze would mash down into the rings, and prevent them from functioning. The operation was then discontinued for some time, until Manganese bronze replaced Tobin. It has actually been proved that a piston head properly welded with Manganese bronze will last as long, or longer, than the original cast iron head, if properly lubricated. Some roads do have failures, but invariably they can be traced back to the fact that the cylinders were run dry at the time the failure occurred.

Blacksmith Shop

The most difficult operation a blacksmith welder has to deal with, is frame welding. When they first began to weld frames with the oxy-acetylene torch, the idea was to see that a filler rod was secured that was exceedingly high in tensile strength. In other words, the impression was, that ductility was not needed in a frame weld. But after a number of successive failures, they began to realize it was not so much tensile strength that was required, as ductility of the rod that was used as a filler, and a weld that would stand the vibration the frame was subjected to on the locomotive. Consequently the high tensile rods were replaced with mild steel. Mild steel rods proved more successful than the high tensile rods, but it was evident that an improvement in filler rods was badly needed, so some of the leading gas companies got busy and developed a rod that had sufficient tensile strength and also retains

ductility, and these rods were found to be satisfactory for frame welding. In order to take care of expansion and contraction on frames, it is always necessary to expand them cold before welds are made. The expansion necessary depends entirely upon the location of the break rather than the size of the frame. It ranges from ⅛ to 5/16 in. when a steel filler rod is used. If the break happens to be on one of the splices that go over or under the cylinder, the bolts are usually removed and all you have to deal with is a loose end. In that case ⅛-in. expansion is all that is necessary. If the break is on a leg or lower rail, 3/16 is sufficient, if on the main rail over the driver, ¼ is the usual allowance. If on the main rail immediately back of the cylinder, 5/16 is allowed because this is the most difficult place on a frame to get expansion, and the more difficult the more expansion should be allowed. When bronze is used, which is standard by many railroads today, the expansion allowance is about, or approximately one-half that allowed for steel.

Regarding the use of bronze or steel. If either is to be used exclusively on all class of frames, I would personally prefer the bronze, because many of the modern locomotives have alloy frames, which if brought to a molten condition somewhat changes the character of the metal at the weld, causing a weak condition in or adjacent to the weld metal. When bronze is used the metal is only brought to a dull red cloor, and the metal characteristics are not changed, therefore, it has been found the most satisfactory method of welding alloy steel frames. It is also more economical because it can be done in less time, with less gas consumption, less preparation work in expanding, and is much easier on the operator.

Now, we have only covered some of the major problems in the locomotive department. I will not attempt to tell of all the operations on a railroad. I have not mentioned car work, where thousands of dollars are saved annually by use of the process. I have not mentioned track work, frogs, switch points and so forth, which are reclaimed daily at big savings. Neither have I mentioned the water works department, bridge and building department, signal department, coach repair department and many other places where the process is used at enormous savings.

Inspection of Welded Steel Framing in Buildings

By FRANZ EDER

✦ A paper prepared by Mr. Franz Eder, Mechanical Engineer of Robert W. Hunt Company's New York organization, and presented November 13, 1930, before the annual convention of the International Acetylene Association, Chicago, Illinois.

MOST industrial developments pass through four typical, successive stages, namely:

Discovery of heretofore unknown or unused properties of materials, processes, or their application in new fields.

Laboratory development on a small scale.

Application of the art by those directly interested in its utilization.

General use of the process on a large scale.

During the first three stages, the inventors, financial and technical sponsors are chiefly concerned with and responsible for the marketability, quality, safety and economy of the processes or product. In its fourth stage, however, such development may affect the general public and the question of its supervision may have to be taken care of by agents of the public.

A development of the type which I have in mind is fusion welding of buildings and other structures. It has advanced rapidly during the last few years and as all the indications point to its more general use in the future, the attention of many authorities has been focused on a study of its proper applications.

The introduction of a new or comparatively new method into general use, such as is represented by the welding of connections of buildings and other structures, deserves particular attention on the part of all interested parties, including municipalities, owners, architects, engineers, contractors and inspecting engineers.

I am of the opinion that the success of industrial and technical development depends among other things on the proper restrictions placed on the enthusiasm responsible for them. Such restrictions operate to prevent poor workmanship, the use of improper materials and methods which, if permitted in even a few cases, may destroy public confidence in an otherwise satisfactory development and impede its progress.

It is worthy of note and to the credit of the fusion welding industry, as applied to buildings and other structures, that it has done a great deal of fundamental and applied research and development work before advocating the general use of fusion welding.

Proof of the large amount of constructive and restrictive work performed by the responsible concerns who sponsor structural welding as well as by a number of fabricators and users, can be found in the standardization and codifications and the procedure controls which cover the most important problems involved.

A. W. S. Code

The code for Fusion Welding and Gas Cutting in Building Construction as formulated in 1929 by the Committee on Building Codes of the American Welding Society, contains definitions and permissible unit working stresses, makes recommendations as to general procedure of designing typical connections, and indicates the proper practices of workmanship in detail.

This code is based on and supplemented by the procedure controls which have been worked out by a number of users, manufacturing interests, and individuals. The various procedure controls cover particular types of construction, take into account the individual problems in their proper order, and specify methods to be followed.

While a great amount of further development in the art of welding of structures will undoubtedly be accomplished in the future by those who have brought it to its present state, the carrying on and carrying out of the supervisory work for the purpose of attaining the highest degree of safety will now devolve chiefly upon owners, architects, engineers, public agencies, and especially upon inspecting engineers.

Purpose of Inspection

A new field for inspection has presented itself, therefore, in the supervision of welding of structures; new, in the sense of having to adapt itself to the re-

cent developments of the art of welding. However, the basic principles of proper inspection are similar for many types of materials and processes, though each individual case requires special treatment and solution of its particular problems.

Broadly speaking, the object of inspection is to obtain compliance with the requirements of specifications, drawings and other stipulations contained in the contract, as well as with recognized standards of good workmanship. The advantage of having requirements agreed upon by purchaser, seller, and other interested parties when contract for work is awarded, is self evident. Such requirements should form part of the contract, and inspecting engineers should receive complete details thereof before their presence on the job is required. Also if any changes of or additions to those requirements are agreed upon by the interested parties after construction has started, the inspecting engineer should be informed accordingly, and at the earliest possible moment.

Many phases of inspection service are based on the process of comparing, such as measuring or testing with a view of ascertaining whether required dimensions or properties of the materials have been maintained, or comparing materials, methods, workmanship and other details with the required stipulations and with the standards which a skilled, experienced and trained inspector fixes in his mind.

This process of comparison which has to be practiced by the inspector as outlined above, may become quite complex in itself. In addition, this work must be based on, supplemented and guided by good judgment, thorough knowledge of and experience in the type of the job in general, and the particular work on hand, thoroughness—all details require exacting attention—and fairness and firmness of decision.

Conditions in shop and field frequently offer problems which are not and perhaps cannot be included in the contract and specifications. Good judgment has to be exercised by the inspector in such cases, which may either have to be decided by himself or his superiors, or be referred to the client for a final ruling.

Finally, the inspector must back up his judgment by a clean cut decision of accepting or rejecting; accepting if all details are properly executed and are found to be in accordance with the requirements, rejecting if the job does not meet the requirements, or is, in his opinion, unsafe or detrimental to the structure or does not represent first-class workmanship or materials.

In addition to the application of general principles of inspection, the special requirements and conditions of individual classes of work must be taken into consideration to be able to supervise properly such work. Some of the features which present themselves in connection with welding of structures are mentioned in the following.

Proper Design

It is essential that the design of fusion welded connections be adapted to this method of construction. A poorly designed connection, even if properly welded, cannot be as efficient as one of correct design welded with equal skill.

The responsibility for the design rests with the architect, or designing engineer, but not with the inspector.

The successful application of welding in structures depends on the coordination of a number of factors, of which proper design is of utmost importance. It is only natural that there should exist a tendency on the part of some designers to utilize details for welded construction which may have been found satisfactory in riveted construction. However, such details should be made with the idea of giving the best result, highest efficiency and adequate safety. Unless this is done and unless the properties of welds and welded joints are fully recognized and taken into account, uniform success cannot be expected. No amount of careful work, skill of the welder, care, training and experience of the inspector can overcome the handicap of improper design.

Welding Inspection

During fusion welding liquefied metal is deposited in small amounts, such metal becoming fused throughout and with the base metal—provided the welding is properly done. This process results in an intimate union of the parts to be joined.

In the inspection of structures, the connections of which are fusion welded, problems are encountered which are different from those found in the inspection of riveting. It is well to recognize this and to understand that different problems may have to be solved by different methods

The appearance of the surface of the completed weld cannot be taken as the final criterion of the soundness of the weld, though an experienced inspector may utilize the appearance of the surface of the weld as an index of the skill of the welder and of the general condition under which the welded metal was deposited, and, therefore, each weld should be closely scrutinized by the inspector after completion.

While the quality of the weld can be determined by a number of tests, such tests generally result in the destruction of the connection and can therefore be made only at random, if at all.

The problem of non-destructive testing of materials has been encountered in many branches of engineering research and in many instances solutions were found. The means which, in my opinion, will give the desired results in the inspection of welded connections for structures is the supervision of the welding operation.

During fusion welding, the liquid metal is deposited in small increments. This introduces a time element which affords opportunity to an experienced inspector for a close and detailed inspection of the welding process and the technique of the welder. The technique of skilled welders is usually quite uniform, their proper manual habits having become a sort of second nature. Ability to pass proper qualification tests depends of course to a great extent on satisfactory manual habits and technique of welding.

In the case of gas welding, a pool of molten metal presenting a mirror-like surfaco is steadily maintained, the liquid advancing evenly and entering the "V" or fillet at a uniform rate. The following features can be observed:

Cleanliness of parent metal.

Condition of the flame.

Pre-heating of the parent metal.

Fusion of welding metal with the parent metal.

Working out of slag which is being brought to the surface.

Location and motion of welding rod and flame.

Penetration into the root of the space provided for the weld.

Use of proper welding rods.

In the case of arc welding, metal is being deposited through the medium of an electric arc and the following characteristics are observable:

Cleanliness of the parent metal.
Current and voltage as recorded on meters.
Proper length of arc.
Position and motion of electrode.
Fusion of welding metal with parent metal.
Manner in which metal is deposited.
Crackling noise and spattering of the metal, if any.
Penetration into the root of space provided for the weld.
Use of proper welding rods.

The observations which have been outlined above will assist an experienced inspector to form an opinion of the skill of the welder, enable him to compare the method used by the individual welder with the details of procedure control and permit him to judge the quality of the weld by the aggregate results of his observations. He will know what to look for before starting the job and have fixed in his mind the various practical aspects of procedure control as referring to the particular construction, its detailed design and the requirements of the contract.

The inspection of welded connections, as outlined in the foregoing, pre-supposes the inspector's presence on the building during the time of welding. This does not mean that the inspector will have to observe the work of each individual welder at all times, a procedure which appears to be unnecessary, as the general observation of the quality of the weld and of the handling of the welding job will indicate the skill of the welder and will permit the inspector to judge whether the required standard of welding operation is maintained throughout the job. At frequent intervals, however, the inspector should observe the work of each welder, systematically supervising all of them.

This method of inspecting welded structures during welding operation may at first appear unusual. Such, however, is not the case. Similar problems which arose in other industries were solved in a similar manner.

Inspection in Other Industries

Robert W. Hunt Company, the company with which I am connected, introduced, 18 years ago, a method of special inspection of steel rails, which embraces a careful and continuous supervision of every stage of development from the charging of open hearth steel furnaces to the finished product. Conditions at the furnaces, soaking pits, blooming mill, shears, rail mill and drop test are under constant observation at all times, with the result that the effects of the practice and workmanship at any stage of the manufacture are subjected to a careful examination, the result of which in the aggregate and taken together with the findings of the final rail inspection determines the acceptability of the rails.

Similarly in the field of concrete construction, a system of complete field supervision utilized by us, consists in testing and inspecting the materials delivered on the job, in supervising their proportioning and mixing in accordance with the requirements for the desired strength. In this case the inspector is in constant attendance during the period of pouring of the concrete, thereby keeping a close check on its uniformity and on the proper setting of the reinforcing, with a view of having reinforcing in position before and during the concreting and obtaining uniformity, strength and safety of the construction.

Similar methods are followed in the inspection of various other materials, but the above two instances will suffice to illustrate the point.

Special Tests and Observations

In addition to the supervision of the actual welding, the inspector can obtain some information as to the quality of the welding by random tests, such as exploring the edges of the weld for penetration and fusion by means of a small chisel or by local remelting of the weld whereby holes, tunneling, improper fusion, insufficient penetration and other defects can be discovered. It is evident that inspection by remelting cannot be applied as a regular procedure. However, should there exist any doubt as to the quality of a particular weld or the work of an individual welder, re-melting may be used to good advantage. Where re-melting is used, proper care must be exercised to rehabilitate the weld.

The standardization of measuring gages has been given attention by the American Welding Society. These gages should be used during inspection, to ascertain whether or not the proper amount of metal has been deposited.

The quality of the welding rods is of great importance. Inspector will have to satisfy himself that the rods supplied to the job conform to the requirements of the specifications, or at least to recognized good practice.

Another important point in the inspection of welded structures is the necessity of having clean parent metal, where the welds are to be made.

The code for structural welding of the American Welding Society recommends that the steel to be welded shall receive a coat of linseed oil only. Therefore acceptance of steel which is painted where welding is to be done should not be made.

These and other details will have to be taken care of during the course of inspection. One of the most essential points, however, which has to be taken into consideration is the proper qualification of each welder to be employed on the job.

Good fusion welding can only be obtained from welders who have successfully passed the qualification tests. No welder should be permitted on the job unless fully qualified. These tests form part of the procedure control, and their carrying out is of extreme importance for the successful execution of the work.

It is essential that the inspector on the job be supplied with definite proof that each and every welder has satisfactorily passed the qualification tests and specifications should stipulate this feature explicitly. The evidence that each welder has satisfactorily passed the required qualification tests may be obtained by the inspector, in the form of a certified record of such qualification tests issued by a reliable source, or else the inspector may actually witness or conduct such qualification tests. It should be clearly stated in the specifications which of the two methods is to be followed on a particular job. After satisfactory evidence has been given, in this respect, the inspector can readily observe whether or not the welder maintains the standard throughout the job, and if not, the inspector should take immediate steps to correct this condition.

Evidently the mere observance of the requirements of welding codes and procedure control can and should be supplemented by the supervision of addi-

tional details. This is typical of inspection of any materials or construction. Theoretical limitations outlining what can be accepted and what should be rejected must of necessity be of a general character, while conditions found in the field, building or shop may present many questions in detail which cannot be foreseen and incorporated in specifications. This has been recognized in many industries by specifying tolerances within which materials may be accepted. Such tolerances should be pre-determined by the interested parties and should be included in instructions to the inspector.

It is apparent that a service as described above, in connection with inspection of fusion welding of buildings, requires the selection of carefully educated inspectors, who have thorough knowledge of the various welding methods.

The procedure of inspection will have to be continually adapted to the progress of the welding industry. This is as it should be. Advance of the art should be accompanied by corresponding changes in the method of inspection.

I firmly believe that competent inspection will perform one of the most important functions in the development of welding of structures.

Reclamation Welding and Cutting

By G. W. LIEBER

✦ This paper was read before the 31st Annual Convention of the International Acetylene Association, Chicago, Ill., Nov. 12, 13 and 14, 1930. Mr. Lieber is Superintendent of Reclamation, Missouri, Kansas and Texas Railroad, Parsons, Kansas.

SOME years ago it became definitely known that oxy-acetylene cutting and welding could be economically applied to certain railroad operations, especially where the cost of dismantling, repairing (by forge welding) and re-assembling was in many instances equal to the price of the original article.

Many experiments and tests were made to determine the possibility of the practical use to which oxy-acetylene cutting and welding could be applied in an efficient and economical manner, and at the same time withstand the severe shocks and strains to which practically all railroad articles are subjected. These experiments developed that not only was this method practical and economical but in many instances superior, as it was possible to reinforce the weld, whereas under the former method it was difficult to maintain the dimensions of an original section.

There are many practical uses to which the cutting torch can be applied, not only to railroads but the industrial field as well, have taken advantage of the opportunities offered through the use of automatic machines for cutting steel plates of every description and design. The development of these machines has made it possible to reduce considerably the cost of forgings formerly used in the manufacture of various articles used by the railroads and other industries. The railroads have likewise found economical use for this machine, and many installations are being made each year. The possibilities offered by the use of automatic cutting machines are beyond comprehension, as new methods and practices are being developed.

The many uses to which the oxy-acetylene cutting torch alone can be applied have never been fully realized, especially with our railroads, and each year we develop further operations that can be more economically performed by using a cutting torch than by the methods formerly applied. One of the most outstanding and profitable developments to the railroads occasioned by the use of oxy-acetylene torch is the preparation of scrap. The railroads produce over 50 per cent of the entire accumulation of scrap in the United States, which amounts to millions of tons per year. Prior to adopting the use of a cutting torch in the preparation of scrap the entire accumulation was sold as a very low grade and the price obtained per ton was lower than the amount received in the past few years for an average classification. Through the use of the cutting torch lower grades of scrap are prepared to higher classification at a small cost per ton. The price received for the higher grades is often five times the actual cost per ton to prepare the scrap with the aid of an oxy-acetylene cutting torch. This method of preparing scrap has been instrumental in giving the railroads many thousands of dollars for their accumulation which was formerly sold to individuals who assorted and prepared to a classification that brought enormous profit. The cutting torch has proved its importance to the railroads and will always be a fixture and necessity to the economical performance of many railroad operations.

Another important use in which the oxy-acetylene cutting torch has been most beneficial to the railroads is in the developing of an efficient and economical method of dismantling cars and locomotives. Until the introduction of the practical use of an oxy-acetylene cutting torch the dismantling of cars, and especially locomotives, was a difficult problem, an operation that was dreaded by all to whom the task of dismantling was assigned, and at the same time an expensive operation to the railroads, whereas with the aid of the cutting torch this difficult task was reduced to a pleasant one, likewise reducing more than 50 per cent the cost to the railroads. Considering the additional price received for the scrap, after being prepared by the aid of an oxy-acetylene cutting torch, I would say the present day cost of dismantling cars and locomotives has been reduced practically 70 per cent over the method used prior to the advent of the oxy-acetylene cutting torch.

Practically every railroad has today an acetylene generating plant adjacent to the scrap dock where the dismantling of cars and locomotives is usually assigned. Often it is found inconvenient to dismantle directly in the scrap yard, while a place may be available several thousand feet away. This distance in no way impairs the practicability of extending the gas lines directly to the dismantling yard. Where stations are placed at convenient intervals the entire operation can be performed just as economically as could be done directly in the scrap yard.

The transportng of oxygen to a manifold located at the dismantling yard incurs little or no additional expense, as the handling cost in either event would be practically the same. The convenience offered in piping oxygen and acetylene directly to the point of operation has effected a saving to the railroads of many thousands of dollars, and this method is, and will continue to be the most practical, efficient and profitable method of dismantling cars and locomotives for many years to come.

Abstract of Thesis on Arc Welding of Nickel Steel

By THOMAS K. McMANUS

✦ This thesis was prepared by Mr. Thomas K. McManus, graduate of the U. S. Military Academy, and submitted in partial fulfillment of the requirement for the Degree of Master of Science from M.I.T.

Procedure

WELDS were made in 3½ per cent nickel steel with the following wires: commercial, chrome-nickel, aluminum bronze, nickel steel and chrome-molybdenum. Tensile, bend, impact and fatigue tests were made of the original and welded material and these physical tests were supplemented by X-ray examination and macro and micro studies.

Composition of Base Metal and Welding Wires

The composition of base metal and welding wires are given in Table 1.

Preparation of Specimens

All specimens were cut from the same sheet of nickel steel in such a way that all welds were made perpendicular to the direction of rolling. Plates were beveled to an opening of 60 degrees. The original metal to be used for test specimens was cut in the following sizes: tensile 19 x 2½ in., bend 5 x 1 in., fatigue 6 x 2 in, and impact 5 x 2 in.

All the metal was then tempered at 600 deg. Fahr. for three-quarters of an hour. It is felt that this was an unnecessary step for comparative results but probably helped to relieve the internal stresses in the original metal. The weld specimens were not subsequently heat treated following welding, so the value of this tempering to specimens that were raised to a higher temperature by welding is doubtful.

The plates were then welded, all welds being a single vee but weld of the non-rigid type. As the welds were to be ground to plate thickness so as to compare weld metal per unit area against base metal per unit area, welding was done from both sides of the plates. Table 2 gives the data on welding.

Plates I using commercial wire were welded by a man who probably would be classified only as a fair welder. The arc held was somewhat erratic causing sputtering, but most of the time was held short. Beads of weld were laid in the vee of the abutting plates successively one on the other until the weld was built above the plates. Three beads were usually required. This method of welding has the advantage in that one layer of deposited metal heat treats the one already laid. However, as noticed in the welding operation and by a microscopic study, the welds contain slag which was probably in the flux coating and had not been properly floated off of the weld metal. The plates for tensile specimens were badly out of line. The fatigue specimens were bent due to the contraction of the weld metal on cooling. The impact and bend specimens were the best made.

The rest of the welds were made by Mr. Reed at the Watertown Arsenal. Mr. Reed has only been welding for a little over a year, but is considered a good welder. The welds were all built up at once instead of in successive layers, the arc welding progressing in a zigzag motion away from the operator with the electrode tilted forward at an angle 15 to 20 degrees from the normal to the plates.

Welds using the chrome-nickel wire appeared good from visual inspection both during the process of welding and after the completion of same. Mr. Reed has had experience welding with this type of wire before.

Welding with aluminum bronze gave considerable trouble. Low current with both straight and reversed polarity was first tried, but poor penetration resulted. Carbon arc welding was then attempted but due to the poor equipment at our disposal it was felt the results would not be satisfactory. Possibly with a smaller carbon and magnetic control of the arc and the cooling of the specimens the author believes there might be a possibility of welding with aluminum bronze successfully. Atomic hydrogen welding was then tried but the welds were extremely porous due to entrapped gas. Arc welding with high amperage was finally resorted to. The welds appeared fine but doubt existed whether the welds could be good using such a high current.

A three-sixteenths of an inch nickel steel wire whose composition closely approached the base metal was next used. This wire was too large for the quarter inch plate. In order not to severely overheat the base

TABLE 1

COMPOSITION OF BASE METAL AND WELDING WIRES

	C	Mn	Si	S	P	Ni	Cr	Cu	Al	Mo	Fe	Sn
Base Metal	0.32	0.61	0.16	0.033	0.015	2.41	....	....	....	....	Bal	....
Welding Wire												
I. Commercial	0.13–0.18	0.40–0.60	0.05	0.04	0.04	....	....	....	....	....	Bal	....
II. Chrome Nickel	0.34	0.67	0.13	0.02	0.01	1.79	0.61	....	....	....	Bal	....
III. (a) Al Bronze	....	....	....	....	....	....	....	90	10	....	....	....
(b) Monel	....	1–2	....	0.06	....	66–68	....	27–30	....	....	1–3	....
(c) P. Bronze	....	....	....	....	0.25–0.40	....	....	95–96	....	....	....	3–4
IV. Nickel	0.15–0.25	0.40–0.60	....	0.04	0.04	3.25–3.75	....	....	....	....	Bal	....
V. Chrome Molybd.	0.40	0.77	0.52	0.015	0.031	....	0.92	....	....	0.24	Bal	....

TABLE 2

DATA ON THE WELDING OF TEST SPECIMENS

Kind of Welding Wires Used	Current (Amps)	Method of Welding	Polarity	Size Wire, In.	Flux Coating	Remarks
I. Commercial	105	Arc D. C.	Straight	1/8	Medium	Tensile plates out of line. Fatigue plates warped due to weld. Welds appear fair.
II. Chrome Nickel	90	Arc D. C	Straight	1/8	Very slight	Welds all good.
III. (a) Al. Bronze	210	Arc D. C.	Straight	1/8	None	Welds appear good.
(b) Monel	145	Arc D. C.	Straight	1/8	Medium	Deep penetration. Heat too High.
(c) P. Bronze	130	Arc D. C.	Straight	1/8	None	Welds appear good. Probably little penetration.
IV. Nickel	140	Arc D. C.	Straight	1/8	Very heavy	Welds good. Wire too large for best results 1/4" plate.
V. Chrome Molyb.	33	Atomic Hydrogen	A. C.	1/4	None	Good welds. In places weld metal not built up high enough.

metal, the current was cut to a minimum. This required a very short arc to be maintained. Although the welds appeared good, it was felt that the results might not be the best because of the low amperage used with that size wire.

The atomic hydrogen method of welding was used in the welding with the chrome-molybdenum wire. The welds were made by "forward welding," the torch making an angle of 45 degrees with the line of the weld. All the welds appeared good. There was some boiling of the metal but this was kept at a minimum. In spots not enough deposited metal was added to build the weld flush with the plate.

Following the welding all specimens were ground to approximately plate thickness. After X-raying they were then cut into test shapes shown in Fig. 1. Except for the tensile specimens of the commercial wire all welds were checked and reground to one-quarter inch plus fifteen thousandths. As the plate metal varied by at least fifteen thousandths from a quarter inch, greater accuracy was not considered necessary. The tensile specimens of the commercial set were so badly out of line that they had to be left oversize.

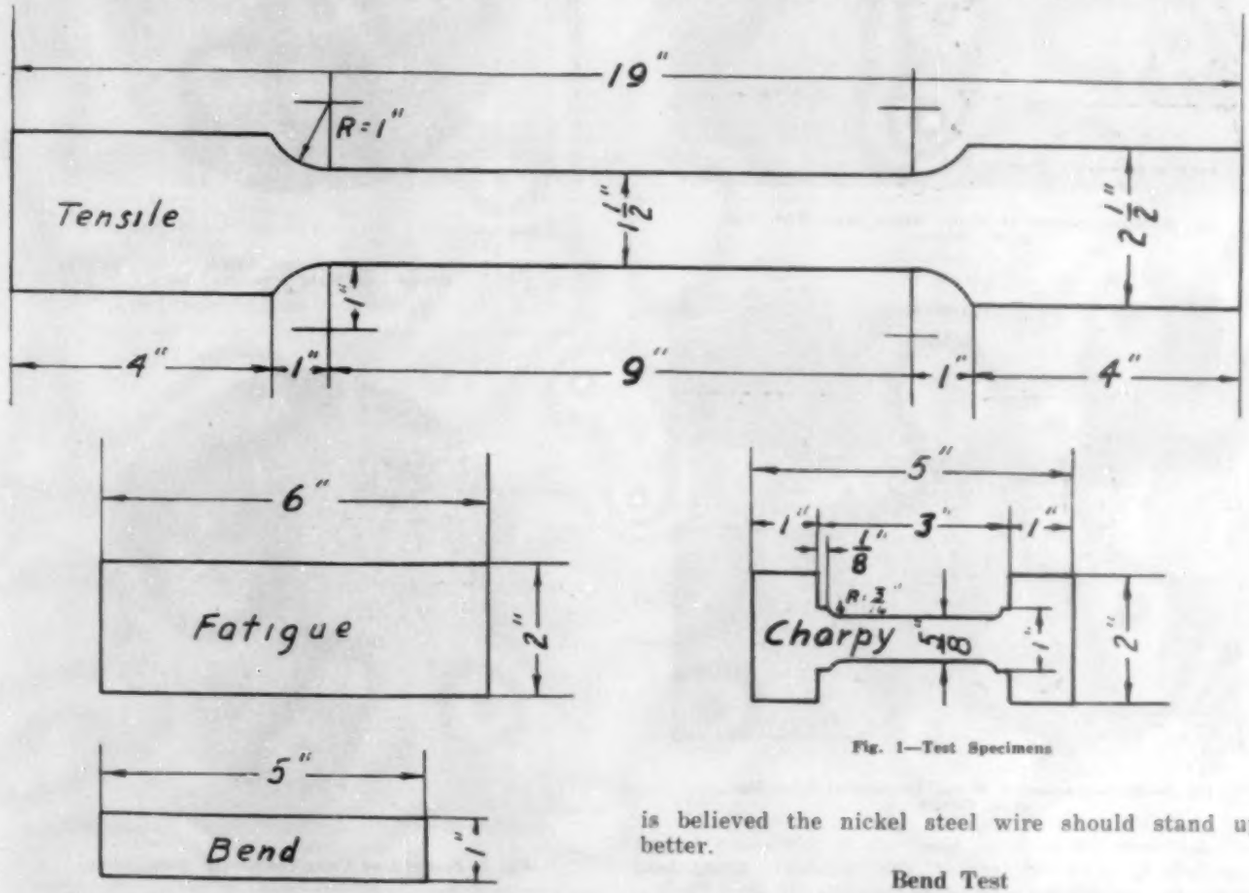


Fig. 1—Test Specimens

X-Ray

The X-ray photographs of the welded joints are not reproduced. In general, it may be stated that the author believes that the X-ray is an excellent non-destructive test of welds and the analysis of the X-ray examinations check very closely with the physical test.

Tension Test

The tensile tests were much as would be expected from the X-ray examination. All the specimens broke in the welds except two of group V, the chrome-molybdenum specimens. Table 3 gives the results obtained from the tensile tests. All specimens were pulled in a 100,000 pound Riehle testing machine.

The tensile strength of the specimens welded with commercial wire was somewhat higher than expected. In figuring the pounds per square inch tensile strength, allowance was made for the extra metal in the weld. The figures given are believed to be within two per cent of the actual pounds per square inch.

The chrome-nickel gave highly satisfactory results —the rupture point being equal to that of the base metal. In one specimen the base metal could be seen necking out almost ready to break. The chrome-molybdenum welds were actually stronger than the base metal which is the ideal to which the welding profession is constantly aiming.

The nickel steel wire gave results near those of the commercial wire, both being near the yield point of the base metal. Under more favorable conditions it is believed the nickel steel wire should stand up better.

Bend Test

The bend tests were made on a Tinius Olson Machine around a pin one-half inch in diameter. The angle when the first crack appeared in the metal was noted. The ultimate angle of breaking was thought to be of little value as the welds were in all cases brittle and broke shortly after the first crack appeared. However, all specimens were broken so as to compare the fractures.

Elongations were obtained from the bending across the weld as is described by W. B. Miller of the Union Carbide Co. in the September 1927 issue of the Journal of the American Welding Society. The results are given in Table 4.

In some cases part of the bending was due to the

bending of the base metal, a fact which is explained by the relative stiffness of the two metals—weld and base metal.

Two points in the bend test were noticed. First, poor penetration could be told by the fracture. Where the base and weld metal had not been properly fused, rupture would occur at that point and was readily noticed by the appearance of the break. Second, the porosity of the metal was made noticeable by the fracture which occurred across the weakest area, i.e. across the area of greatest porosity.

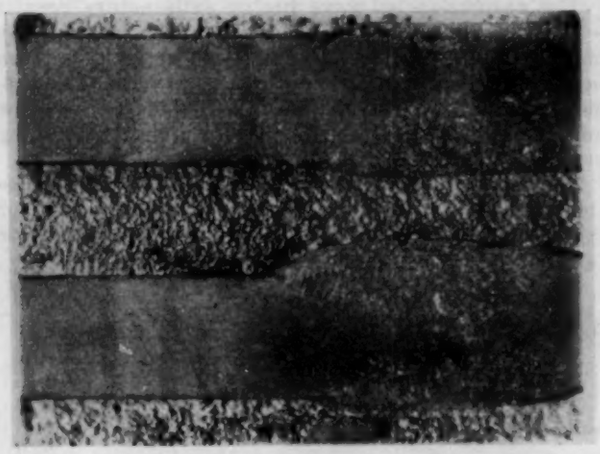


Fig. 2—Microstructure of Welds, Nickel Steel Wire Top. cr-mo. Bottom

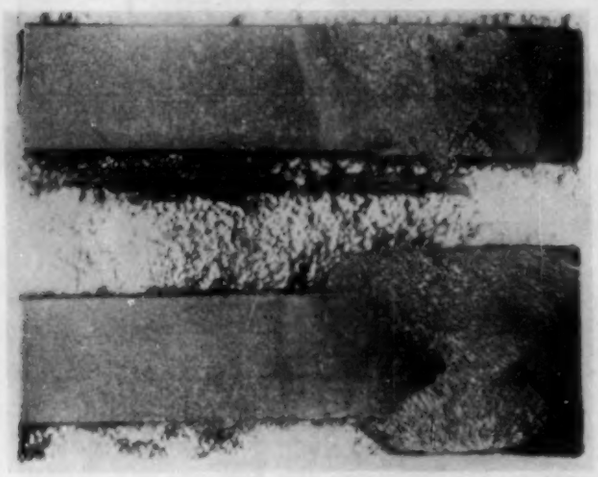


Fig. 3—Microstructure of Welds, Commercial Wire Top. cr-ni. Bottom

Impact Test

The impact tests were made on a large "Moulton Pendula" Charpy testing machine. Table 5 gives the results of the test.

The results lacked uniformity even in the original metal. The values of the chrome-molybdenum were low even though in two cases the original metal broke instead of the weld metal. Comparative results are the chief value obtained from Table 5. The relative impact values of the welds are the same as those for the tensile test, commercial lowest, then nickel steel, chrome-nickel, and chrome-molybdenum in order. The Charpy test is actually a tensile test that occurs in a very small fraction of a second, so somewhat similar results might be expected.

Fatigue Test

An Olsen Repeating Stress testing machine was used to get the fatigue results.

The data again show the chrome-molybdenum comparable with the base metal and the chrome-nickel somewhat lower but standing quite high. The nickel in spite of its porosity gave results well above the commercial wire and aluminum bronze. All the commercial specimens were bent out of shape by welding, so probably the poor showing of this metal was partially due to the high stress initially put into the specimen on straightening it in the jaws of the machine. The aluminum bronze results were again disappointingly low.

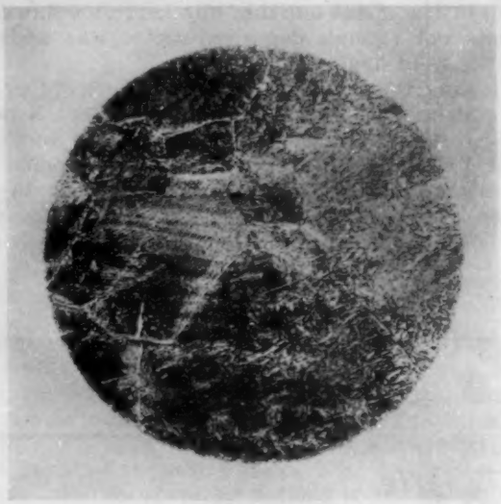


Fig. 4—Fusion Zone. Chrome Nickel Weld. Showing Heated and Weld Structure. 100×

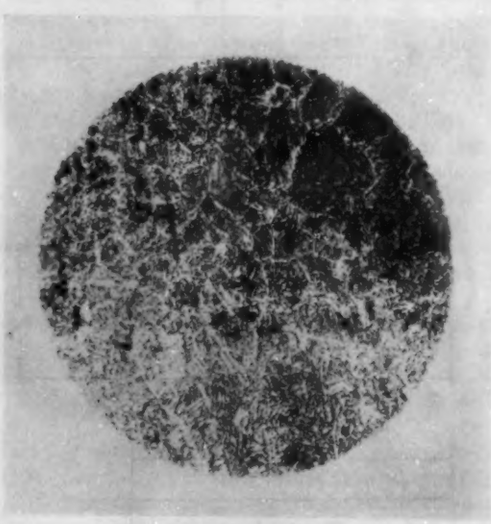


Fig. 5—Fusion Zone Using Commercial Wire. 100×

Hardness Test

Hardness test of the weld metal was made with a Shore Monotron machine. It is believed this machine gives excellent results if data of a series of tests are plotted of the penetration—stress curve and the aver-

HARDNESS RESULTS

Specimen	Monotron Reading	Corresponding Diamond Brinell Number
Original Metal	23	209
Commercial	19	171
Chrome Nickel	20	180
Aluminum Bronze	25.5	237
Nickel	21	190
Chrome Molybdenum	34	312

TABLE 3
RESULTS OF TENSILE TEST

Specimen	Yield Point Lbs.	Ultimate Lbs.	Yield Point Lbs./sq. in.	Ultimate Lbs./sq. in.	Elong. In. 8 In.	Elong. In. 1 In.	% Elong. (8 in.)	(Across Weld) % Elong. (1 in.)
Orig. (a)	25,160	37,290	67,000	99,500	1.38	0.17	17.2	17
(b)	24,900	37,400	66,400	99,800	1.38	0.17	17.2	17
(c)	24,500	36,460	65,300	97,200	1.43	0.18	17.9	18
I. Com. (a)	.....	24,900	.....	61,500	0.05	0.05	0.63	6
(b)	.....	25,510	.....	62,000	0.10	0.07	1.25	7
(c)	23,100	27,570	62,000	68,000	0.18	0.04	1.88	4
II. Cr. Ni. (a)	25,600	36,300	68,300	96,800	0.53	0.09	6.62	9
(b)	25,670	37,840	68,400	101,000	0.84	0.12	10.50	12
(c)	25,760	35,780	68,500	95,400	0.42	0.08	5.25	8
III. Al. Br. (a)	.....	6,700	.....	17,900	0.03	0.03	0.37	3
(b)	.....	19,110	.....	51,000	0.03	0.03	0.37	3
(c)	.....	10,820	.....	28,800	0.02	0.02	0.25	2
IV. Ni. (a)	25,420	29,030	67,800	77,500	0.20	0.10	2.50	10
(b)	25,500	28,100	68,000	74,900	0.21	0.08	2.62	8
(c)	.....	24,800	.....	66,000	0.11	0.10	1.37	10
V. Cr. Mo. (a)	25,700	37,930	68,500	101,200	1.19	0.06	14.9	6
(b)	24,500	37,720	65,300	100,500	0.50	0.15	6.25	15
(c)	24,480	36,030	64,300	96,100	1.13	0.01	14.1	1

TABLE 4
RESULTS OF BEND TEST

Specimen	Angle of Cracking (Degrees)	Elong. from Formula (Per cent)
Orig. (a)	At least 180	33 (Approx.)
(b)	At least 180	33 (Approx.)
(c)	At least 180	33 (Approx.)
I. Com. (a)	25	9
(b)	25	9
(c)	25	11
II. Cr. Ni. (a)	40	9
(b)	45	9
(c)	85	9
III. Monel (a)	20	10
(b)	30	15
(c)	30	15
Phos. Br. (a)	20	7
(b)	15	6
(c)	18	6
IV. Ni. (a)	30	15
(b)	70	18
(c)	20	10
V. Cr. Mo. (a)	60	10
(b)	70	14
(c)	120	10

age slope through zero used to obtain the corrected reading. The results using this method are given in the table.

A. Procedure control is absolutely necessary for the advancement of welding.

B. Nickel steel can be welded with the tensile, fatigue and impact properties of the weld equal to or exceeding the base metal.

C. Chrome-Molybdenum welding wire produced the best welds with respect to all the mechanical properties.

D. On specimens not subsequently heat-treated, welded specimens on account of their lack of ductility break with little warning.

E. The X-ray examination of a weld is an excellent nondestructive test of a weld.

F. The base metal affected by the heat of welding is changed, but not detrimentally so if the welding is carried out properly.

G. As deposited from the wire the weld shows the characteristics of cast metal.

TABLE 5
CHARPY IMPACT RESULTS

Specimen	Foot-pounds	Remarks
Original (a)	788	.....
(b)	817	.....
(c)	740	.....
I. Commercial (a)	41	.....
(b)	128	.....
(c)	55	.....
II. Chrome Ni. (a)	370	.....
(b)	140	.....
(c)	300	.....
IV. Nickel (a)	70	.....
(b)	308	.....
(c)	64	.....
V. Chrome Mo. (a)	529	Broke in base metal
(b)	377	.....
(c)	529	Broke in base metal

TABLE 6
RESULTS OF FATIGUE TEST

Specimen	No. of Reversals	Fiber Stress Lbs./Sq. In.	Break	Corrected No. Reversals
Orig. (a)	24,784	27,500	Top Jaw	6,972
	6,272	42,200	Top Jaw	.....
(b)	9,176	42,200	Top Jaw	9,176
(c)	8,928	42,200	Top Jaw	8,928
I. Com. (a)	384	43,400	Weld	504
(b)	574	42,700	Weld	705
(c)	208	42,200	Weld	208
II. Cr. Ni. (a)	6,324	42,200	Weld	6,324
(b)	2,726	44,700	Weld	4,800
(c)	161	53,900	Weld	4,930
	713	49,600	....	.....
III. Al. Br. (a)	775	41,500	Weld	724
(b)	78	36,700	Weld	31
(c)	325	41,500	Weld	304
IV. Ni. (a)	2,542	39,800	Weld	1,650
(b)	2,232	41,500	Weld	23,080
(c)	5,208	37,400	Weld	1,540
V. Cr. Mo.	5,301	39,800	.....	.....
(a)	4,464	42,200	Top Jaw	7,904
(b)	13,392	39,800	Weld	8,680
(c)	8,928	41,500	Top Jaw	8,330

Compressive Tests of Bases for Subway Columns

By JAMES H. EDWARDS
H. L. WHITTEMORE
and
A. H. STANG

✦ Mr. Edwards (deceased) was Chief Engineer of the American Bridge Co.; Mr. Whittemore is Chief, Engineering Mechanics Section, U. S. Bureau of Standards; Mr. Stang, Engineer, U. S. Bureau of Standards. This report is also presented in the United States Bureau of Standards Journal of Research.

I. THE COLUMN BASES

IN the construction of subways under the streets for carrying passengers by electric trains it is customary to provide steel columns between the tracks to support the overhead structure. These columns are usually rolled steel H-sections having plate and angle bases riveted to the column for distributing the load on the concrete footing.

The American Bridge Co. suggested to the Interborough Rapid Transit Co., of New York City, that the bases be welded instead of riveted and that the design of the base be changed to one which was more suitable for this new method of fabrication. The welded base consisted of only three plates, as shown in Figs. 1, 5 and 8. Six angles and two plates were required for the riveted base having no base plate, as shown in Figs. 1 and 8, six angles and three plates for the riveted base having a base plate, as shown in Figs. 1, 2, 3, 7 and 8.

As the welded design was a radical departure from the method of fabricating these important connections, which experience had shown to be satisfactory, tests were made to determine the strength of 3 welded bases and 6 riveted bases, 3 without base plates and 3 with base plates. Some hand strain-gage readings were taken to study the stress distribution.

The American Bridge Co. made the designs and fabricated the specimens. The tests were made by the National Bureau of Standards.

II. METHOD OF TESTING

1. Loading the Specimens

The specimens rested on two blocks, *A-A*, having cylindrical lower surfaces as shown in Fig. 2. The blocks rested on a hardened steel plate, *B*. The blocks were 6 in. wide and 10 in. long. The radius of the cylindrical surface was 4 in. The distance between the inner surfaces of the blocks, 6 in., was about the nominal depth (5.986 in.) of the H-section. The span was, therefore, 12 in. A hardened steel plate, *C*, was placed on top of the H-section and the load applied through a spherical bearing, *D*.

With an assumed yield point of 35,000 lb./in.,[2] the H-sections (sectional area 14.70 sq. in.) would be expected to fail in compression under a load of about 500,000 lb. The testing machine having a capacity of 600,000 lb. was therefore used for these tests. The riveted bases without base plates failed when loaded in this machine, but as the other specimens did not fail under a load of 600,000 lb., greater loads were later applied in the hydraulic testing machine having a capacity of 10,000,000 lb. (see Fig. 3). Since the lower platen of this machine has a spherical seat no spherical bearing was used on top of the H-section.

2. Strain Gage Measurements

To determine the stresses in some portions of the specimens, hand strain-gage readings were taken on the gage lines (shown in Fig. 1) with a Whittemore fulcrum-plate strain gage having a 2-in. gage length. This strain gage (shown in Fig. 4) was designed by one of the authors at the request of the Engineering Foundation, Committee on Arch Dam Investigation.[1] For that investigation a more accurate strain gage was desired than the instruments then available.

The frame of this instrument consists of two parallel side bars connected near their ends by spring fulcrum plates which effectively prevent motion of one bar relative to the other, except longitudinally. The two points (for insertion in holes in the member upon which the measurements are to be taken) are rigidly attached, one to each side bar. The relative movement of the side bars is, for an instrument having a 2-in. gage length, usually indicated by a "Last Word" dial micrometer graduated to 1/10,000 in. and having a range of 0.024 in. Although the accuracy of the readings of this strain gage depends somewhat upon the skill of the observer, the error in the stress computed from the readings taken with this instrument having a 2-in. gage length, probably, did not exceed 2,000 lb./in.^{2} The error would have been much smaller (about 500 lb./in.^{2}) if the gage length had been 10 in.

On the riveted column bases, strain-gage readings were taken only on the four inclined gage lines, *6*, on the outstanding leg of the stiffener angles.

Twenty gage lines were used on the welded specimens as shown in Fig. 1 to obtain a better knowledge of the stress distribution in this new design.

To allow the average stress to be determined if the stiffener buckled, the gage lines 1, 2 and 3 were placed on both sides of the stiffener.

III. RESULTS OF THE TESTS WITH DISCUSSION

1. Strength of the Bases

The results of the compressive tests are given in Table 1. In addition to the strength a "yield point" was obtained by observing either the load at which the beam of the testing machine "dropped" or the load which remained constant as the specimen shortened. As it was necessary to stop the testing machine to take the strain-gage readings, it was difficult to detect "yield points" by "drop of the beam" at loads near those at which strain-gage readings were taken.

The first indication of failure in the welded specimens was buckling of the stiffener plates. The H-section deformed as the load increased. The welded specimen TC 1-A after test is shown in Fig. 5. All the welded specimens failed in much the same way. In only one of the welded specimens, TC 1-A, was a crack in the weld detected. It was not observed until after the specimen was removed from the testing machine. It was at A (Fig. 5) between the outer surface of the flange of the H-section and the weld metal and extended along the weld for about three-fourths inch. It

[1] Engineering Foundation Committee on Arch Dam Investigation, Report by Committee, 1, published by Am. Soc. of Civil Engrs., Strain-Gage, p. 64; May, 1928.

was probably caused by the increase in the angle between the base plate and the flange of the H-section when the H-section deformed. The crack was so small that it could have had no effect on the results of the test.

All the riveted specimens without base plates failed by shearing the eight rivets on one side. Specimen TC 2-A after test is shown in Fig. 6. There was no noticeable deformation of the H-section nor of the pieces forming the base.

The computed average maximum shearing stress in these rivets, using the nominal area of the 16 three-fourth-inch rivets, was 59,400 lb./in.[2]

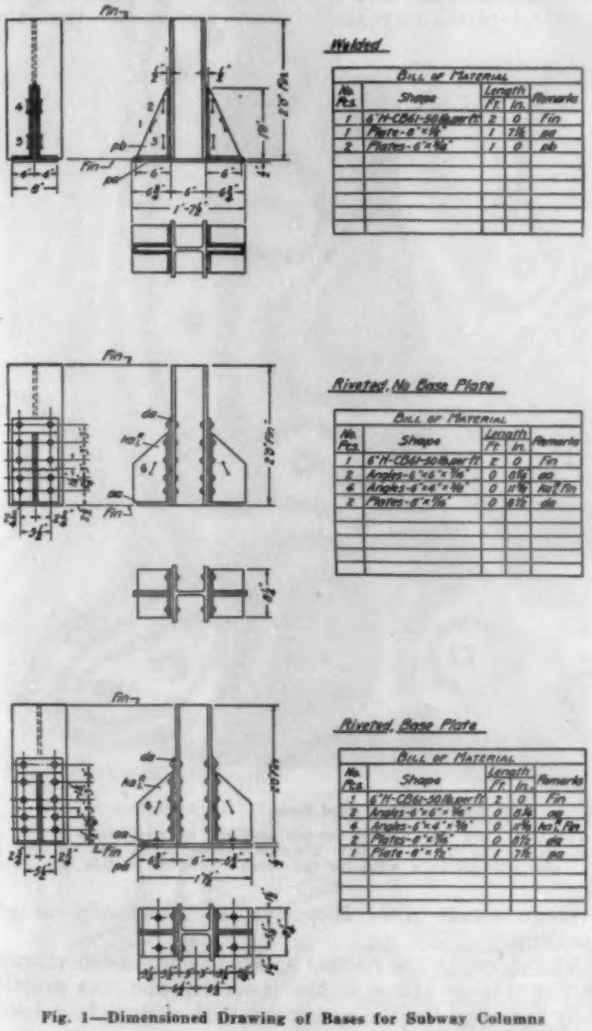

Welded
Bill of Material
No. Pcs. | Shape | Length Ft. | In. | Remarks
1 | 6"H-C861-50 lb. per ft. | 2 | 0 | Fin
1 | Plate-6"×⅜" | 1 | 7½ | ea
2 | Plates-6"×⅜" | 1 | 0 | ea
Riveted, No Base Plate
Bill of Material
No. Pcs. | Shape | Length Ft. | In. | Remarks
1 | 6"H-C861-50 lb. per ft. | 2 | 0 | Fin
2 | Angles-6"×6"×⅜" | 0 | 6½ | ea
4 | Angles-6"×4"×⅜" | 0 | 11⅝ | As Fin
2 | Plates-6"×⅜" | 0 | 8½ | ea
Riveted, Base Plate
Bill of Material
No. Pcs. | Shape | Length Ft. | In. | Remarks
1 | 6"H-C861-50 lb. per ft. | 2 | 0 | Fin
2 | Angles-6"×6"×⅜" | 0 | 6½ | ea
4 | Angles-6"×4"×⅜" | 0 | 11⅝ | As Fin
2 | Plates-6"×⅜" | 0 | 8½ | ea
1 | Plate-6"×⅝" | 1 | 7½ | ea

Fig. 1—Dimensioned Drawing of Bases for Subway Columns

The failure of the riveted specimens with base plates was similar to that of the welded specimens as may be seen in Figs. 3 and 7. The outstanding legs of the stiffener angles buckled, several rivets sheared, and the H-section deformed.

The strength of these particular welded specimens was practically the same as the strength of these particular riveted specimens having base plates. The strength of the riveted specimens without base plates was 61 per cent of the strength of the riveted specimens having base plates. Unfortunately, no tensile specimens of the steel in these column bases were provided by the fabricator. There is no record as to whether the H-sections were cut from the same or from different lengths. It is therefore impossible to draw general conclusions from the results of the tests. As there was considerable deformation of the H-sections for the welded and riveted base-plate specimens and comparatively little deformation of the base, it is probable that

Table 1.—*Results of compressive tests of column bases*

[Nominal area of H-section, 14.70 square inches]

Column base No.	Description of specimens	Yield point		Strength	
		Total load	Stress in H-section	Total load	Stress in H-section
		Pounds	*Lbs./in.*[2]	*Pounds*	*Lbs./in.*[2]
TC 1-A	Welded	[1] 412,000	28,000	633,000	43,000
TC 1-B	do	444,000	30,200	665,000	45,200
TC 1-C	do	448,000	30,500	661,000	45,000
	Average				44,300
TC 2-A	Riveted, no base plate	395,000	26,900	419,000	28,500
TC 2-B	do	353,000	24,000	426,000	29,000
TC 2-C	do	367,000	25,000	416,000	28,300
	Average				28,600
TC 3-A	Riveted, base plate	435,000	29,600	698,000	47,500
TC 3-B	do	446,000	30,400	693,000	46,500
TC 3-C	do	440,000	29,900	676,000	46,000
	Average				46,600

[1] At this load no drop of the beam was observed, but the stiffeners were buckled.

Fig. 2—Specimen Ready for Test in the Testing Machine Having a Capacity of 600,000 Pounds

The base was supported on a span of 12 inches by blocks having cylindrical (radius 4 inches) lower surfaces. A spherical bearing block was placed on top of the specimen. This specimen is riveted base TC 3-C having a base plate

the maximum load was determined by the strength of the H-section.

As the maximum compressive strength of columns decreases as the length increases, the strength of the short H-sections used for these tests was greater than the strength of any longer column having the same section. It may also be pointed out that the bases, when in use, rest on flat surfaces supported by the foundation of the subway. Since these bases were tested on blocks which were spaced 12 in. center to center, they were, therefore, tested under more severe conditions than those which could occur in service.

2. Stresses

The location of the gage lines on which strain gage readings were taken is shown in Fig. 1. The stress

[2] For method of computing stress from strain-gage readings, refer to B. S. Tech. Paper No. 260, "Tests of Some Girder Hooks," by Whittemore and Stang, p. 310.

along a gage line was computed[2] by multiplying the change in the length of the gage line by the assumed Young's modulus of elasticity of 29,000,000 lb./in.^{2} for the steel. The readings for gage lines similarly located were averaged for specimens of the same type.

(a) Stresses in the Stiffeners

The stresses in gage No. 1 on the stiffener plates of the welded specimens, TC 1, may be compared with

Fig. 3—A Specimen After Test in the Testing Machine Having a Capacity of 10,000,000 Pounds

This is the riveted base TC 3-A having a base plate. The total load was 698,000 pounds and the average stress in the H-section was 47,500 lbs./in.^{2}

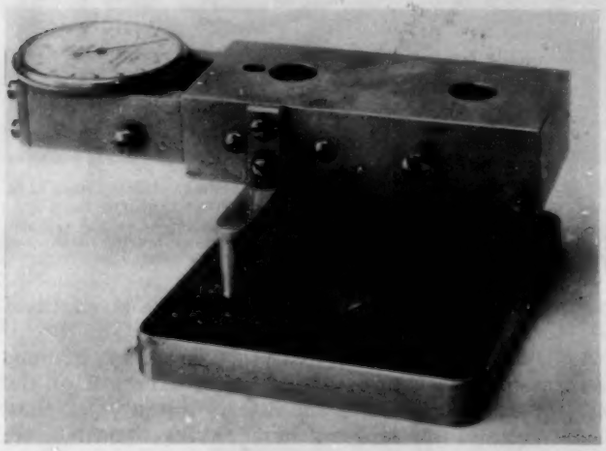


Fig. 4—The Whittemore Fulcrum Plate Strain Gage Having a Gage Length of 2 Inches

those in gage No. 6 on the stiffener angles of the riveted specimens TC 2 and TC 3. It should be remembered that the combined thickness of the two angles in the riveted specimens (three-fourth inch) is equal to the thickness of the stiffener plates in the welded specimen.

For convenience in plotting the graphs of Fig. 8, the ordinates are the average stresses in the H-section computed from the load indicated on the beam of the testing machine, while the abscissas are the stresses computed from the strain-gage readings. Each plotted point is the average of the six readings obtained for the two gage lines on opposite sides of the specimen for each of the three specimens. The stress in the stiffener plate (gage No. 1) is proportional to the average stress on the H-section up to about 18,000 lb./in.^{2} and is more than twice the stress in the stiffener angles of the riveted specimens (gage No. 6). This shows that the riveted base is stiffer than the welded. The gage lines, Nos. 1 and 6, are in the same position relative to the base and the column. The greater stiffness of the riveted specimens is undoubtedly due to the fact that the stiffeners on the riveted bases had considerably more metal outside the gage lines than the stiffeners on the welded base. For higher loads the stresses in the stiffener plates increased much more rapidly than the

Fig. 5—The Welded Base TC 1-A After Test

The total load was 623,000 pounds and the average stress in the H-section was 42,400 lbs./in.^{2} The crack shown at A was the only one detected in a weld for the three specimens of this type

average stress in the H-section, and eventually caused buckling.

The stress in the riveted specimens was proportional to the average stress in the H-section and was practically the same for the specimens with and without base plates.

Although base plates on the riveted specimens increased the maximum load about 60 per cent, they did not increase the stiffness of the base for loads below the yield point.

The stresses in the vertical gages Nos. 2 and 3 (Fig. 1) on the stiffener plates of the welded specimens are plotted in Fig. 8. The stress in gage No. 2, 9 in. above the base, was directly proportional to the average stress in the H-section throughout the loading range for which strain measurements were taken.

The stresses in gage No. 3, 3 in. above the base, were about the same as those in gage No. 2 up to about 8000 lb./in.^{2} For higher loads, however, the stresses in gage No. 3 increased more rapidly than the stress

in gage No. 2 and were much less than those in the inclined gage No. 1. It appears probable that the upward forces exerted on the specimen by the blocks, A-A (Fig. 2), caused high compressive stresses in the stiffeners above the blocks. Although gage No. 3 was not vertically over the block, it was in the portion of the stiffener which was highly stressed.

(b) Stresses in the H-Section

Strain gage readings on the H-section were obtained on only the welded specimens, TC 1. These gage lines

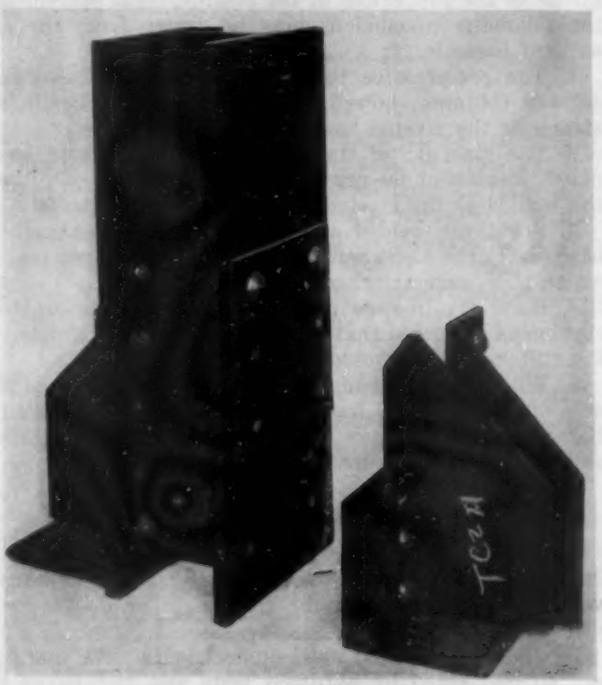


Fig. 6—The Riveted Base TC 2-A Without Base Plate, After Test

The eight rivets on one side of the specimen sheared. The total load was 418,000 pounds, and the average stress in the H-section was 28,480 lbs./in.^{2} The average shearing stress in the sixteen $\frac{5}{8}$-inch rivets was 59,400 lbs./in.^{2}

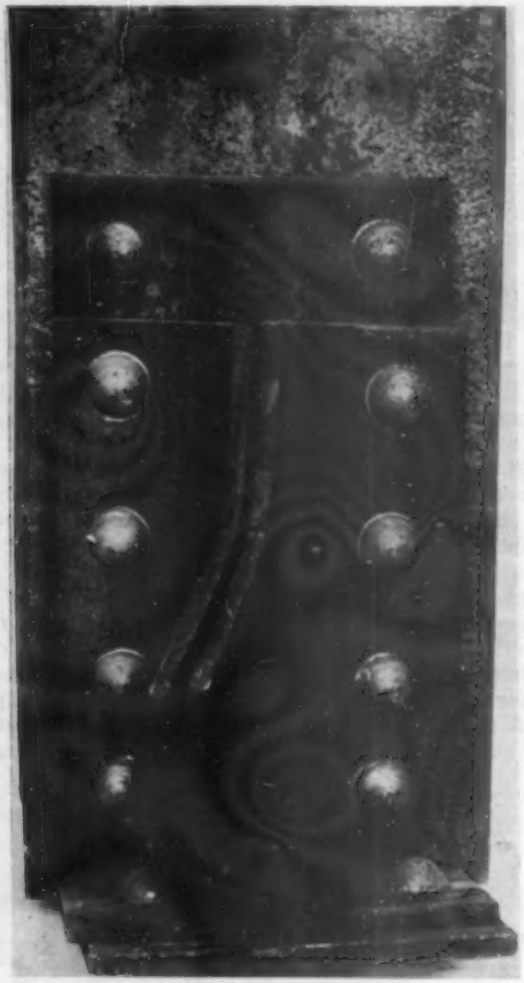


Fig. 7—The Riveted Base TC 3-C Having Base Plate, After Test

The total load was 676,000 pounds, and the average stress in the H-section was 46,000 lbs./in.^{2}

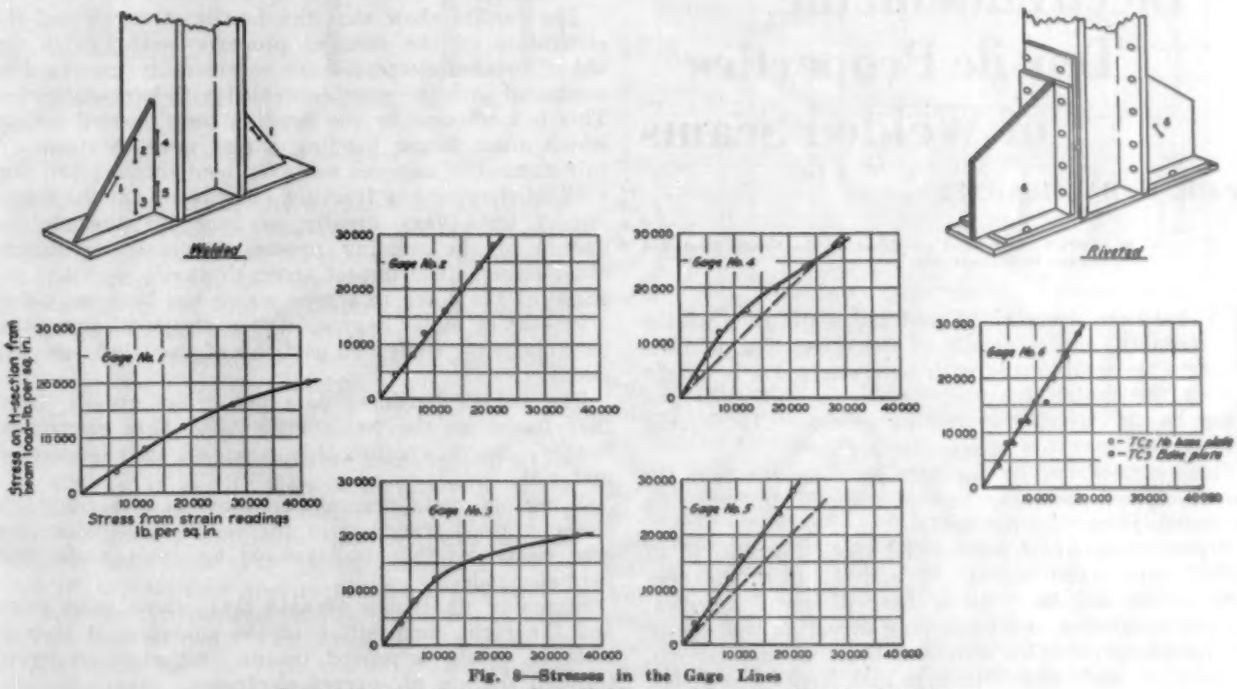


Fig. 8—Stresses in the Gage Lines

Gages 5 Nos. 1 to 5 were on the welded bases and gage No. 6 on the riveted bases

(Fig. 1) were vertical and centered 9 in. for gage No. 4 and 3 in. for gage No. 5 above the lower end of the H-section. The stresses on these gage lines have been plotted in Fig 8. The dashed line is inclined 45 deg. to the axes and may, therefore, be called a line of theoretical stress since, if the load on the H-section was uniformly distributed over the cross-section, the strain-gage stresses would equal the average stress computed from the total load on the specimen. Because of the stiffeners and the base plate and the fact that the specimen was supported on a span of 12 in., it is obvious that a uniform stress distribution should not be expected near the base of the H-section. Fig. 8 shows that the stresses in gage No. 4, 9 in. from the bottom of the H-section, were less than the average stress in the H-section for low loads, but practically equal the average at 26,000 lb./in.^{2} The stresses in this gage line were proportional to the average stress from zero to 8000 lb./in.^{2} load, but for higher loads the stress increased more rapidly than the average, and indicated that the effect of the stiffeners in reducing the stress in this portion of the H-section flange was decreasing rapidly. The change in the direction of the stress curve for gage No. 1, gage No. 3, and gage No. 4 (Fig. 8) indicates that above 12,000 lb./in.^{2} average stress in the H-section, the stiffeners carried a progressively lower portion of the load. It might be advisable to use a thicker stiffener. For low loads the stresses in gage No. 5 (Fig. 8), 3 in. above the base of the H-section, were about equal to those in gage No. 4 and were practically proportional to the load throughout the test, being about 70 per cent of the average stress in the H-section. For the higher loads, they were lower than those in gage No. 4, The stress in the web of the H-section, near the base plate, must, therefore, have been low. At gage No. 5 the stiffener was wider than at gage No. 4 and was more effective in transmitting the forces to the H-section.

IV. CONCLUSIONS

On the assumption that there were no great variations in the properties of the steel in these specimens, the following conclusions may be drawn from the results of these tests:

1. The compressive tests of these welded bases for subway columns showed that they were practically as strong as the riveted bases having base plates.
2. The strength of these riveted bases without base plates was about 60 per cent of the strength of either the welded or the riveted bases having base plates.
3. For these welded and these riveted bases having base plates the bases were as strong as the H section to which they were attached.
4. Hand strain-gage measurements on these welded specimens indicated that an increase in the thickness of the stiffener plates would make the bases stiffer.
5. With the base loaded on a span of 12 in. the stiffness of these riveted bases up to the yield point of the H-section was the same for the bases with base plates and without base plates.

Investigations on the Influence of Covered Electrodes on the Tensile Properties of Welded Seams

By DR. K. BAUMBARTEL

✦ Abstract of material published by the Verein Deutscher Ingenieure in Bulletin 336.

IT has been ascertained that the diminution of the strength, and especially of the elongation, of electric arc welds made with bare electrodes is chiefly due to the material absorbing oxygen and nitrogen from the air during the welding process. To prevent this, dipped or covered electrodes are used.

Tests carried out by Kantner have proven that the use of dipped electrodes has no material influence on the tensile properties for welds.

A great number of commercial steel sheets of 6, 12 and 20 mm. (approx. ¼, ½ and ¾ in.) thickness were welded together, using four different asbestos-covered electrodes, and employing direct as well as alternating current. To obtain a basis of comparison, welds were made also with bare and dipped electrodes. Depending on the thickness of the sheets, the seams were prepared for plain, or for single or double-Vee butt welds.

Tensile bending, and notch-impact tests were carried out, supplemented by hardness tests and metallurgical examinations. For each test, the welding current and welding voltages were measured, the consumption and waste of electrodes calculated and the welding depth ascertained.

The results show that the tensile strength and the elongation of the samples properly welded with the aid of covered electrodes are considerably increased as compared with the samples welded with bare electrodes. This is confirmed by the bending tests carried out, in which much larger bending angles were obtained. A fair number of samples was even bent through 180 deg. without showing any fracture. The results of the notch-impact tests vary greatly as here the thermic influence of the welding process becomes particularly conspicuous. The impact strength varies with the position of the notch in a zone which has been heated to a greater or lesser degree. Often also local structural irregularities (embedded particles of slag) influence the result.

The brinell hardness does not differ greatly from that found on the welds made with bare electrodes, but is always greater than that of the non-welded material.

X-ray and metallurgical examinations reveal a much closer grained structure in the welds made with covered electrodes than is possessed by welds made with bare electrodes.

Summing up it can be said that, given good work and the right composition of the covering, it is possible to obtain improved tensile properties in welds through the use of covered electrodes.

Effect of Current on Strength and Ductility of Arc Welds

By CYRIL D. JENSEN

✦ Professor Jensen is Assistant Professor of Civil Engineering, Lehigh University.

IT is believed that in many plants where arc welding is done, the importance of selecting the proper current for each job is underestimated. In order to bring out this point more clearly, an investigation was made for which many similar specimens were prepared, each welded with a different current. Two different sets of specimens were made, one set for the purpose of studying butt welds and the other set for the purpose of studying fillet welds.

The specimens were furnished by the International Motor Company (Mack Trucks) of Allentown, Pa., and were made up by one of their expert arc welders. The laboratory classes in strength of materials at

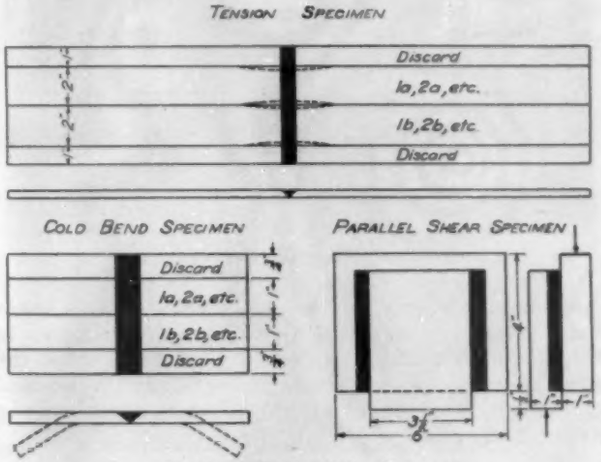


Fig. 1—Make Up of Specimens

Lehigh University made the actual tests as part of their class work, recorded the observations, and computed the unit stresses and the percentages of elongation. Structural steel, meeting the standards of the American Society for Testing Materials, was used for all specimens. The welding wire conformed to the standards for structural steel welding as established by the American Welding Society.

Specimens

The butt-welded specimens were made in pairs (see Fig. 1), that is, 1a and 1b were originally part of the same plate. Immediately following the welding of a tension specimen a duplicate specimen was welded for the cold bend tests (Fig. 1) and numbered to correspond to the tension specimen. As noted in the figure, both the tension and cold bend specimens were single-vee butt-welded. The Summary of Results, Table I, gives in tabular form the data used in making the specimens as well as the results obtained.

Following the preparation of the butt-welded specimens, fillet-welded specimens for the purpose of testing welds in shear were made by the same welder using the same make of wire. As noted in Fig. 1, ⅜-in. fillet welds were employed to join inch plates with laps, as indicated. The Summary of Results, Table II, shows that three series of specimens were prepared under varying currents, one size of wire being used with each series.

Methods of Testing

The tension specimens were tested in the usual manner in a 50,000-lb. two-screw testing machine.

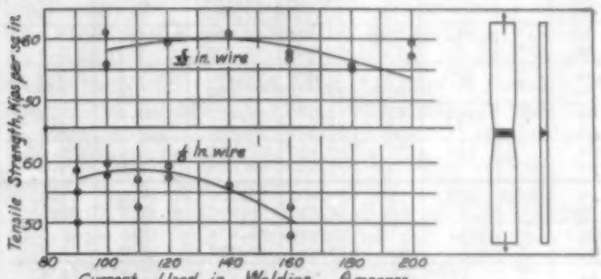


FIG. 2 BUTT WELDS - TENSION TEST

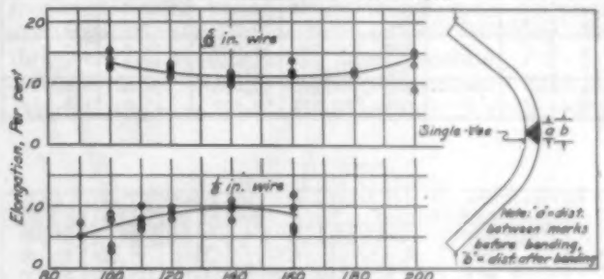


FIG. 3 BUTT WELDS - COLD BEND TESTS

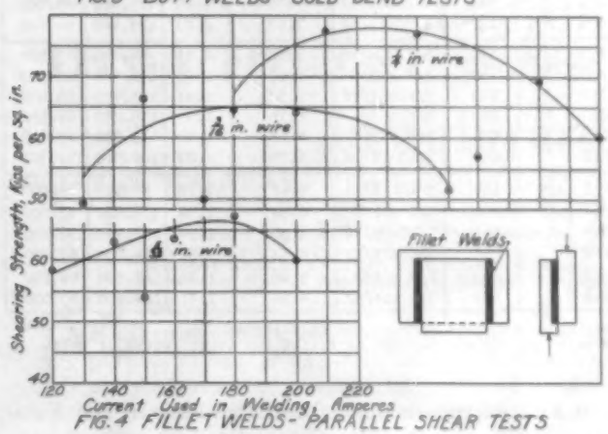


FIG. 4 FILLET WELDS - PARALLEL SHEAR TESTS

Previous to testing, the welded sections were machined down, as shown in the sketch in Fig. 2, reducing the area to insure fractures in the welds.

The cold bend specimens (Fig. 5) were tested by the methods suggested by Mr. W. B. Miller and Mr. A. B. Kinzel, both of the Union Carbide and Carbon Laboratories. The specimens were first bent approximately 30 deg. at points 2 in. from either side of the weld, as shown by the dotted lines in Fig. 1. Then each specimen was placed in a vise end on and force was applied, as indicated by the arrows in Fig. 3. Under increasing load the specimen was found to bend more and more, gradually assuming a shape similar

to one of those shown in Fig. 5. Previous to the test, marks ½ in. apart had been placed across the welds. As each test progressed the outer fibers were stretched to their limits. At the first sign of cracking the specimen was removed and the elongation measured. Since the methods of determining the percentage of elongation as given by Miller differs slightly in a few details from that given by Kinzel, both sets of results have been included in the Summary.

TABLE I.
SUMMARY OF BUTT-WELDS

Spec. No.	Wire Diam.	Current Amperes	Area Sq. in.	Ultimate Load Total	Ultimate Load Lb/sq. in.	Elongation-per cent Miller	Elongation-per cent Kinzel
1a	1/8	90	.762	41,850	54,900	5.4	5.2
1b	"	"	.707	41,475	58,660	7.2	5.3
2a	"	100	.70	41,750	59,700	2.9	3.7
2b	"	"	.706	40,910	57,980	8.7	7.9
3a	"	110	.555	31,600	57,000	10.0	8.0
3b	"	"	.75	39,545	52,730	8.0	6.4
4a	"	120	.555	32,880	59,240	9.2	9.9
4b	"	"	.555	31,780	57,200	8.0	8.9
5a	"	140	.555	31,160	56,200	10.9	7.9
5b	"	"	.560	30,870	55,200	10.0	9.6
6a	"	160	.767	40,450	52,700	6.1	6.8
6b	"	"	.562	27,450	48,800	11.8	9.8
7a	5/32	100	.552	30,900	56,000	14.0	13.0
7b	"	"	.562	34,240	61,000	12.7	15.5
8a	"	120	.552	33,000	59,800	10.0	11.0
8b	"	"	.562	33,450	59,520	13.0	12.7
9a	"	140	.552	33,520	60,600	11.2	9.6
9b	"	"	.536	32,700	60,900	11.7	10.8
10a	"	160	.555	31,960	57,600	12.0	11.2
10b	"	"	.540	30,560	56,500	13.7	11.2
11a	"	180	.552	30,380	55,000	12.0	11.8
11b	"	"	.562	31,250	55,550	11.0	11.6
12a	"	200	.562	32,170	57,400	15.0	14.6
12b	"	"	.544	32,300	59,400	13.0	8.9

TABLE II.
SUMMARY OF FILLET-WELDS

Spec. No.	Wire Diam	Current Amperes	Fillet Weld Section	Length of weld-inches	Area** Sq. in.	Ultimate Load Total	Ultimate Load Lb sq. in
C 1	5/32	120	11/32x11/32	6.70	1.61	94,210	58,500
C 2	"	140	3/8 x 5/16	6.62	1.52	96,000	63,100
C 3	"	160	3/8 x 3/8	6.75	1.79	113,960	63,700
C 4	"	180	3/8 x11/32	6.80	1.63	109,600	67,200
C 5	"	200	5/16x13/32	7.00	1.75	105,000	60,000
C 6	"	150*	13/32x13/32	7.00	2.03	109,440	54,000
C 7	3/16	130	3/8 x 7/16	6.62	1.92	95,000	49,500
C 8	"	150	3/8 x 3/8	6.62	1.76	119,000	67,600
C 9	"	170	7/16x 7/16	6.50	2.01	100,400	50,000
C10	"	200	3/8 x 3/8	6.75	1.79	115,000	64,300
C11	"	230	3/8 x 3/8	6.62	1.76	115,530	65,600
C12	"	250	7/16x 7/16	6.75	2.09	108,000	51,700
C13	1/4	180	5/16x 5/16	6.62	1.39	89,800	64,600
C14	"	210	3/8 x 1/4	6.62	1.39	107,800	77,600
C15	"	240	5/16x 5/16	6.50	1.37	105,900	77,300
C16	"	260	3/8 x13/32	6.62	1.84	104,900	57,000
C17	"	280	3/8 x 3/8	6.62	1.76	121,800	69,200
C18	"	300	3/8 x11/32	6.59	1.71	102,800	60,000

*Welders choice of current for that series
**Based on minimum section of fillet and total length of weld.

The fillet-welded specimens were tested in a 300,000-lb. four-screw Olsen testing machine. A downward load was applied, as shown in Fig. 6; therefore, the stress on the welds was parallel shear. As noted in the photograph, a small roller, bearing against a vertical surface, and a bolt were used to hold the specimen vertical during the test.

Results of the Tension Tests

The strength-ampere curves (Fig. 2) show peak values for both sizes of wire used. It has been the author's experience that the drooping of the ends of the curves for specimens welded by less expert welders was more pronounced than indicated in the curves presented. That is, with the current setting just right for welding, a mediocre welder might secure ultimate strengths approaching those by the expert welder; whereas with other less favorable currents the ultimate strengths would probably be considerably less than shown in the curves.

Due to the lack of sufficient tests the exact location and shape of the curves could not be ascertained. This applies also to the curves for the bend and shear tests. However, considering that the two curves in Fig. 2 and the three curves in Fig. 4 all show the same general shape it seems proven that the amount of current does have an appreciable effect on the strength of welds.

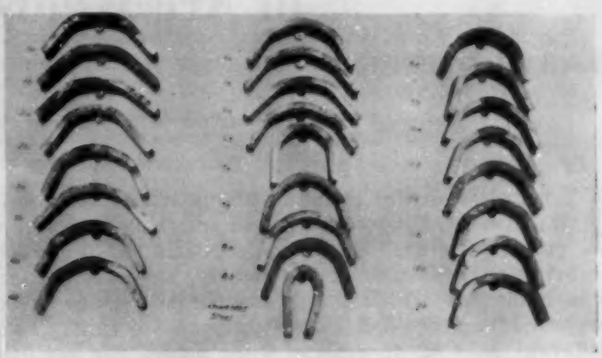


Fig. 5—The Cold Bend Specimens After Being Tested

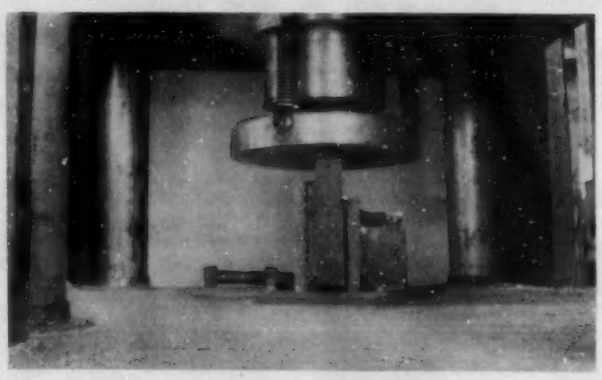


Fig. 6—Set-up for the Fillet Weld Test

Results of the Bend Tests

The results of the cold bend tests, as shown by the curves, Fig. 3, indicate that current may or may not have an effect on the ductility of weld metal. The two curves, one for ⅛-in. wire and one for 5/32-in. wire, appear to be at variance with each other, and therefore conclusions can hardly be drawn. It is to be noted that the general range of the elongation is from 5 to 15 per cent. Considering that structural steel shows an elongation of over 35 per cent by this same test, the results of the tests on the welds are rather disappointing. It becomes quite evident that welded joints should be designed to be stronger than the steel joined so that any deformations will be taken up in the steel and not in the welds.

Results of the Shear Tests

As noted previously the fillet-welded specimens were tested in parallel shear. An attempt was made to hold the size of fillet weld constant at ⅜ in. for all specimens, but a variation was noted and duly recorded. On account of this variation in size of fillet

welds, it was considered better to give the resultant ultimate strengths in pounds per square inch of minimum sectional area rather than in pounds per linear inch of weld.

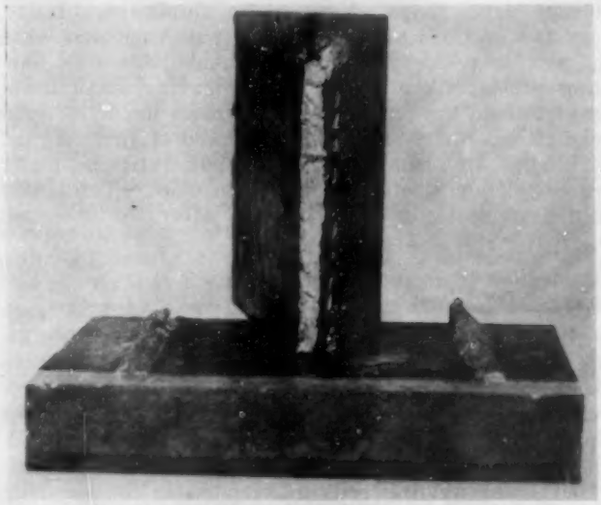


Fig. 7—A Fractured Fillet-Welded Specimen Showing Break Through Minimum Section of the Weld

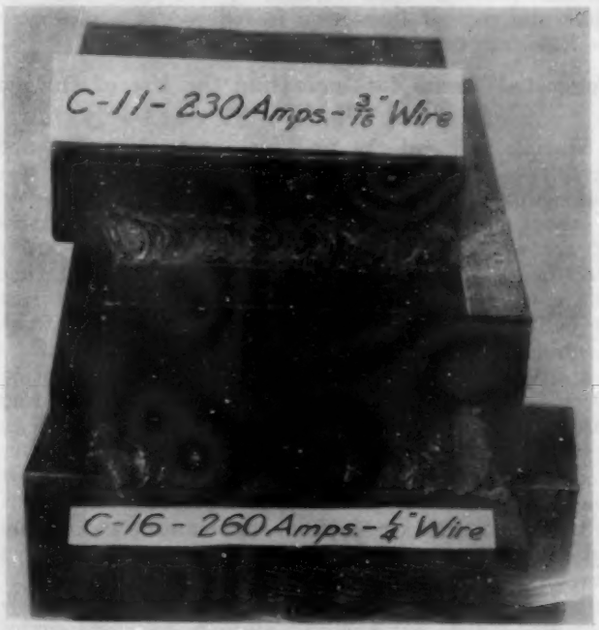


Fig. 8—Showing Smooth Welds Produced with Relatively High Currents

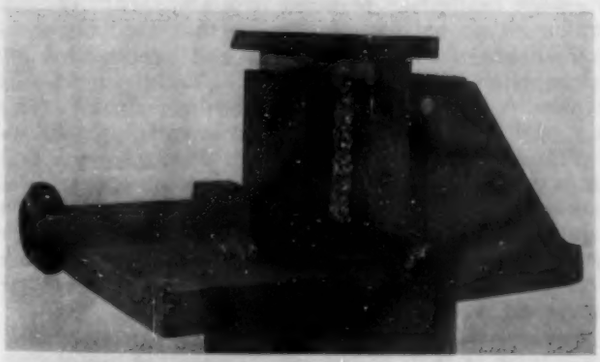


Fig. 9—Fillet Welded Specimen (C14) and Jig Used to Hold Specimen Vertical During the Test

The strength-ampere curves, Fig. 4, show some interesting results. As in the butt-weld tests, peak values were obtained. The curve for the 3/16-in. wire, however, was difficult to ascertain due to some erratic values. It is to be noted that the peak values move to the right as the size of wire increases. Also comparing the curve for 5/32-in. wire with the curve for the same wire in the butt-weld tests, it is seen that the peak of the strength-ampere curves moves to the right with increase in thickness of plates welded.

From an inspector's standpoint the higher currents for fillet welds are much to be preferred. Fig. 8 shows a picture of two specimens welded at rather high currents. The welds are smooth and regular. The steel has a clear, healthy appearance. There is no overlap. Every sign points to strong flawless welds thoroughly fused into the parent metal. The specimens welded at lower currents, on the other hand, were not so regular and in some cases contained overlap, which naturally created some doubt as to the perfection of the fusion.

One of the most unusual findings of this investigation was that the specimens welded with the ¼-in. wire gave strengths considerably higher than those welded with the smaller wires. Since only a few such specimens were tested there is some hesitation in making the statement as holding true in every case. However, the results found herein should give confidence to those welding engineers who have hesitated using ¼-in. wire where full strength is required.

Working Against Time and Cost with the Oxy-Acetylene Processes in Shipyards

By JAMES W. OWENS

✦ This paper was read before the 31st annual convention —International Acetylene Association, Chicago, Illinois— November 12, 13, 14, 1930. Mr. Owens is Director of Engineering, Welding Engineering and Research Corporation.

THE expression *"Time Is Money,"* and the legal phrase *"Time Is the Essence of the Contract"* aptly express the managerial policy of a modern shipyard in the United States. Indeed, the *time factor* has become so important in ship construction and repair that the operating departments of at least one shipyard have come to feel that their Sales Department has modified the phrase to read *"An impossibly short time is the essence of the contract."*

With the sharp competition prevailing between shipyards, the usual order of sales procedure is to appeal to the customer first on the basis of *price*, second on *performance* of the ship in service, and third on *time of delivery*. The third, and frequently the clinching appeal is for a time of delivery as good or better than the nearest competitor. Time of delivery is sometimes of such great importance to the customer that a penalty clause is added to the contract.

As a result of the foregoing, the management of

the type of shipyard referred to has adopted, and is looking for, equipment and processes which will aid the securing of work on the basis of either *price, performance* or *time of delivery*, and preferably on all three.

How then do the oxy-acetylene processes (heating, cutting and welding) fit in this picture? Do these processes supply a real need in ship construction and repair, and if they do, are they meeting other competitive processes on *price*, on *performance*, and time?

In answer to the first question, viz.: do the oxy-acetylene processes supply a real need? Unquestionably, the answer is "Yes," for oxy-acetylene heating, cutting and welding torches have become so essential in modern ship construction and repair that it would be impossible to build or repair ships in the United States at present prices and in the "impossibly short" scheduled time without their aid. In this connection, one has only to be told that the consumption of oxygen and acetylene in shipyards in the United States for last year was over 50,000,000 and 21,000,000 cu. ft. respectively to realize that this is no idle statement.

Heating

Oxygen and acetylene are used for *heating* because their thermal performance insures the localized concentration of a greater number of heat units than is possible with any other combination of gases, thereby *reducing the time* required to do the job. A reduction in time also makes possible a *reduction of cost* by reducing the number of hours of labor required. Specific heating applications are the removal of buckles in plates, the straightening of damaged structural members and parts, and forming. On naval and merchant ships, the use of the heating torch has practically resulted in the abandonment of the forge, and on naval ships, the volume of oxygen and acetylene used for heating, cutting and welding is so great that it requires several days to charge the number of cylinders required when the fleet is outfitted for a battle practice cruise.

Cutting

At present, *the cutting out of rivets and the cutting of plates and shapes* consumes the largest volume of oxygen and acetylene in a shipyard. Here again the performance of these gases insures their use. This is particularly true for rivet cutting because the *shorter the time* the ship is in drydock, the *less the drydock charges and loss of revenue* to the ship owner.

When a ship's bottom has to be removed, the schedule time is invariably so short, and the demand for gas cutters is so great that it is usually impossible for a shipyard to meet it through its regular employment channels. To solve this problem, the Newport News Shipyard requires all student arc and gas welders to take a course in the cutting of metals before commencing their welding course.

The special suitability of these gases for rivet cutting in a shipyard is due to the *shorter time* required to pre-heat the rivet, especially rusty rivets, than is required by other gases, and because it is possible to remove the rivet without damaging the hole, as frequently occurs when the carbon arc is used. As there are usually thousands of rivets to be removed in a bottom repair job, the importance of *reduced time* for pre-heating and the non-injury of rivet holes is apparent. Damaged rivet holes frequently mean the scrapping of a plate at considerable cost and appreciable loss of time.

In the cutting of plates and shapes, the flexibility of the oxy-acetylene cutting process makes possible *lower costs*, and *shorter time* to do the work, for instead of transporting the work to shears, planers, etc., the torch is carried to the work, wherever it may be—storage yard, shops, skids, or on shipboard. Today, very few sections are removed by punching, and when the section removed is of some appreciable size, handling problems are facilitated by leaving small uncut areas to hold the part removed in place until the bulkhead or other part of the ship is placed aboard. Again, port holes are usually never cut out until the plates are completely riveted or welded in place. The cutter then systematically cuts one hole after the other on board the ship.

Welding

Coming now to *welding*, we find the welding torch used extensively for the welding of all the non-ferrous metals and light sheet steel. Applications which have recently come more into vogue are the use of bronze welding for the repair of cast iron and the welding of piping systems, both in the shop and on shipboard. The reasons for this latter application are that recently developed welding rods make possible the securing of a joint having physical characteristics equal to or better than the base metal, the metal can be deposited in any position (flat, vertical or overhead) and the time and cost of inspection is reduced to a minimum as leaks are practically eliminated.

Suggested Means for Increasing the Use of Oxygen and Acetylene

Having specified the principal uses of oxygen and acetylene in a shipyard, I will next consider means for increasing the use of these gases.

About eight years ago, when I recommended to users of arc welding that they consider the use of larger electrodes and higher current values to reduce time and cost, a protest was made by some manufacturers on account of their inability, at that time, to furnish machines to supply the higher currents required. Having observed the performance of oxy-acetylene heating torches, tested practically every cutting and welding torch on the market, and experimented extensively with submarine cutting torches. I am led to the conclusion that oxy-acetylene equipment now supplied for the uses referred to is comparative in its limitations to the commercial arc welding equipment of eight years ago, viz.: its inability to comply with the extremely exacting and heavy demands required of it in present commercial practice. Let us consider a few specific instances. I do not know of any oxy-acetylene equipment which is specially designed along engineering lines for heating as required in a shipyard. That is, equipment so balanced in design that the volume of gases needed for intensive, quick and localized heating are supplied without increasing the acetylene pressure to, what is generally considered, the danger point. This lack of balanced design is also true in equipment for the cutting of heavy sections. In this latter case, these limitations of present equipment were observed when, due to the scrapping of an electrolytic oxygen producing plant, acetylene was substituted for hydrogen. I have several times suggested the need of a torch for the cutting of holes for assembly purposes, and hope some day to see such a torch in common use.

Insofar as *the welding of heavier plate is concerned*, my opinion is that, to further increase the use of oxy-acetylene in this class of work, it will require not only

a thorough analysis, in the remotest detail, of equipment design but a thorough coordination of all details of technic and the utilization of many minds and the best talent available.

Conclusions

In conclusion, I would like to call your attention to the fact that the Newport News Shipyard, the largest user of oxygen and acetylene, is at the same time considered the largest user of arc welding among merchant shipyards. The point that I desire to emphasize is that the extended use of arc welding in this yard has not decreased the consumption of oxygen and acetylene. In comparing navy yards, this ratio is probably also true, although figures are not available. Again, experience has shown that the greater the number of applications in a shipyard wherein oxy-acetylene is considered to be irreplaceable from the economic standpoint, the greater the reluctance of that yard to utilize any other gas. Finally, it is apparent that the oxy-acetylene processes as at present utilized in shipyards supply a need which no other process can, in most cases, compete with on one or all of the three factors, cost, performance, and time. Nevertheless, it is believed that a marked increase of oxygen and acetylene can be secured in shipyards by a consideration of the problem from the standpoints outlined or intimated.

Notes on Application of Code for Fusion Welding and Gas Cutting in Building Construction

By GILBERT D. FISH

✦This paper was presented by Mr. Gilbert D. Fish, Consulting Engineer, Westinghouse Electric & Manufacturing Company, at a meeting of the New York Section of the American Welding Society, November, 1930.

THE Code for welding and gas cutting in buildings is a specification of safety requirements. It goes beyond most building codes in furnishing brief instructions as to workmanship instead of confining attention to the required results, but it does not deal with design beyond specifying allowable stresses and a few other limitations.

Application of this Code is divided naturally into two parts, one being its enforcement in the execution of construction work and the other its observance in designing members and their connections.

Conformity with the Code in execution of welding and related operations is effected by a system of supervision known as procedure control. It includes verification of quality of equipment and materials, qualification of welding operators, and inspection of workmanship during and after execution of the work. The consulting engineer, who may or may not be skilled in the inspection of welding, should familiarize himself with the requirements of safety and make definite provision for checking of each item by a competent inspector. Likewise municipal or other public authorities, charged with verifying the safety of building structures, should adopt and enforce regulations covering inspection, preferably employing inspectors who have had at least a few weeks of intensive training in welding school. The contractor is not generally responsible for the safety of a finished structure, but to insure acceptance of his work and for other obvious reasons, he should procure suitable equipment and materials and should employ a welding supervisor of known ability to examine all unknown welding operators and to take personal responsibility for compliance of all welding work with specifications.

The consulting engineer, the public superintendent of buildings and the contractor should all know that it is safer and less expensive to prevent poor welding being done than to discover and correct it afterward. The wise engineer makes provision for examining

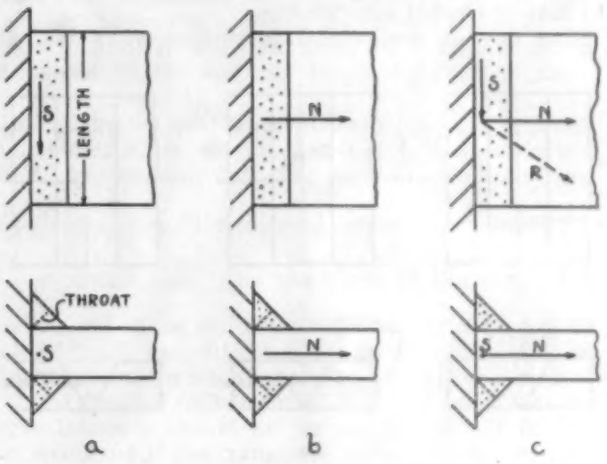


Fig. 1

welding operators before they start work, unless he knows that the contractor's organization definitely excludes unqualified men. A simple and fairly inexpensive provision, which serves all three interested parties without duplication of work, is a brief examination applied to all operators before employment. This requires the operator to execute several samples of work in the form of test specimens, under the immediate observation of an inspector; the examination consists in the observation of the man's technique and in some sort of destructive testing of the specimens. Mere breaking of the welds and examination of the location and character of the fracture generally furnish sufficient evidence, but quantitative strength tests in a laboratory are even more positive. The ability of all operators to make satisfactory welds, with the equipment and welding wire at hand, having been established, it is possible for experienced inspectors to make sure that the required standard is maintained during the work; they observe each operator at work from time to time, and inspect every completed weld for external indications of quality and for agreement with the drawings before paint is applied. The Building Code Appendix contains helpful information and illustrations concerning technique and surface indications of good and bad qualities.

No exposition of control methods by words and pictures can establish what degree of certainty is attained by them or how elaborately they should be

applied in any given case. The history of welded building construction, embracing a wide variety of buildings, designing methods, personnel and control procedure, lacks any instance of structural failure and thereby proves that the method is controllable in practice, but of course, does not prove that all work conformed to standards similar to those of the Code. For most of the work welders have been qualified on the basis of past performance or informal examination by inspectors, not by laboratory tests of specimens made expressly for the job in hand. Close inspection of all welding after completion and of each operator's workmanship from time to time during execution, has usually been required.

There is ample reason for the engineer, the building inspector and the contractor to feel confident, that the employment of experienced inspecting personnel with necessary authority is sufficient precaution when combined with a suitable routine and good engineering design, to insure safety fully equivalent to that of riveted construction.

The day of mechanical inspection of welds, affording positive grading of completed welds at moderate cost, has not arrived. If human inspection and other established precautions had been found insufficient as practical insurance against failure, or if other construction processes such as riveting or the mixing and reinforcing of concrete were safeguarded by means independent of the human element, welding in its present state might be considered unduly dependent on skill and care. The facts of the matter are, that prevailing methods of inspection have not failed in practice, that other methods of construction can no more be inspected automatically than welding, and that defective welds are more readily recognized than burned or loose rivet shanks, weak concrete or misplaced concrete reinforcing bars. It is true that welding requires more skill and care than heating and driving rivets, and for this reason emphasis is placed on qualification tests for operators, but it is also true that the effects of poor workmanship in welding are more readily detected than the results of overheating rivets or of driving them too slowly to fill the holes.

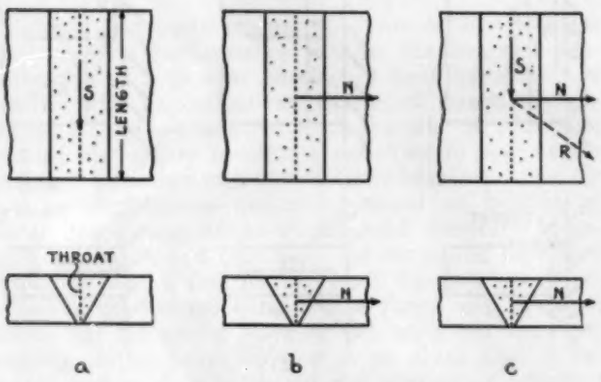


Fig. 2

While safety control of the welding itself is indispensable and is at least as important as safe design, it is a routine matter and is far less a problem for professional attention than is design. The many welded structures already completed bespeak the existence of successful control methods, but some of the designs have left much to be desired in economical application of the welding method. Some joint designs have revealed lack of attention to important secondary stresses or to bending moments caused by eccentricity, and therefore have reduced the safety factor available to take care of imperfection in material and workmanship.

Designing the members of a welded building framework, as distinguished from designing the connection, is not very different from the corresponding work in

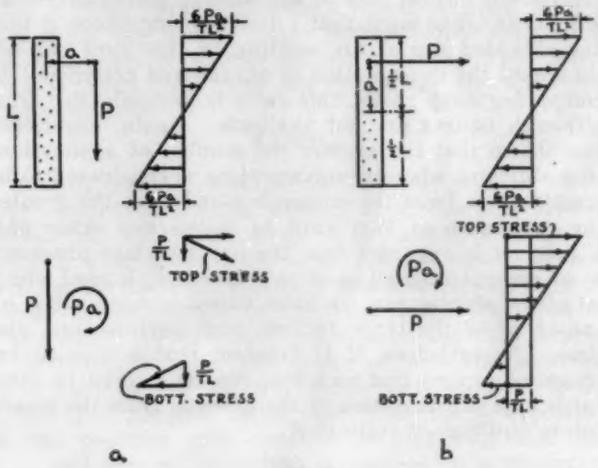


Fig. 3

riveted design. On the other hand, designing welded connection calls for more foresight and judgment than the detailing of riveted joints. Welded connection details require more engineering skill but less drafting labor than riveted ones, because of their far greater variety with smaller number of parts.

A building design adapted to riveted construction can, as a rule, be modified to suit welding by substituting welded connection details for the riveted ones and making changes in designs of any trusses, plate girders, built-up columns or other composite members which may be included. Occasionally it is advantageous to make some lines of beams continuous, as in reinforced concrete construction, especially if wind pressure requires high bending resistance at beam-to-column connections. In commercial buildings, where roof trusses, crane runways, machine supports, balconies and other special forms of framework do not commonly occur, most of the differences between welded and riveted design are in the joints, and a single set of framing plans with column schedule may be used with two sets of typical connections as the basis for alternative bids on welded and riveted construction.

There will be little opportunity to consider types of welded joints, either as to stress analysis or as to suitability for various purposes. Discussion will be confined to procedure for designing an individual fillet weld or butt weld to resist a given external stress, secondary bending stresses in beam connections, and the chief differences between welded and riveted designs for built-up members.

Fillet welds may be loaded in longitudinal shear, as in Fig. 1a, or in transverse shear and tension combined, as in Fig. 1b, or in oblique stress, as in Fig. 1c. In each case the throat section is assumed to be the critical section, its area being the throat dimension times the length of the weld. Tests show that rupture occurs approximately in the throat section, and that the ultimate strength or rupture load is proportional

to the area of this section. In longitudinal shear, the stress is not uniformly distributed along the length of the weld at ordinary working loads, but does approach uniform distribution before failure occurs. As is customary in dealing with shearing stresses generally, the *allowable unit stress means allowable mean unit stress.* In transverse stress, the throat section is subjected to an oblique stress, i. e., shear and tension combined. Tests show that the ultimate strength is slightly greater in transverse than in longitudinal loading, but not different enough to warrant a separate working stress; therefore transverse stress is conventionally regarded as a case of shear in the critical section. Evidently the working strength of a fillet weld in either longitudinal or transverse stress is equal to the area of the throat section multiplied by the unit allowable shear, 11,300 lb. per square inch. It follows naturally that the same values of working strength applies to oblique stress, as in Fig. 1c, the oblique stress being the resultant of a longitudinal stress and a transverse stress. Under the code, the strength of a fillet weld is the same for *all directions* of stress.

A butt weld, whether of the type illustrated in Fig. 2 or any other recognized by the code, is usually employed in tension or compression, as shown in Fig. 2a. The working strength is then the area of throat section multiplied by the unit working stress, 13,000 lb. per square inch for tension or 15,000 lb. per square inch for compression. It may be used in longitudinal shear,

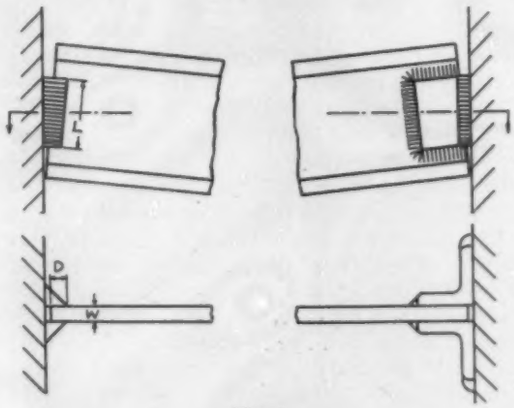


Fig. 4

Fig. 2b, in which case the working strength is the area of throat section multiplied by the allowable unit shear 11,300 lb. per square inch. A butt weld is not ordinarily used in transverse shear (i. e., shear parallel with the throat), and this case is not illustrated or recommended, because there is likely to be an indeterminate bending stress in addition to shear on the throat section. A combination of direct stress with longitudinal shear may occur as in Fig. 2c; in this case the throat section should be designed either for the shear at 11,300 lb. per square inch or for the *resultant stress R* at the allowable value for normal stress (13,000 for tension or 15,000 for compression), whichever requires the larger area. This use of the oblique resultant as if it were normal stress is presumably a little on the safe side, being a compromise between the normal stress on the critical plane and the major principal stress which acts on an oblique plane.

The cases of loading thus far considered are all central or *concentric* stresses. In case the resultant stress on a weld is eccentric, a moment of bending or torsion must be considered in addition to a central stress.

In Fig. 3a, the narrow rectangle represents either a fillet or a butt weld, and the arrow denotes an eccentric longitudinal force applied to one of the plates or other parts joined by the weld. Resolving this force P into a longitudinal shear P applied in the line of the weld and a moment P.a, the shear P is considered to produce a unit stress, in all parts of the critical section, equal to P divided by the throat section area TL, and the moment P.a is quite logically assumed to induce a uniformly varying stress which is zero at the mid-point of length and is $\frac{6Pa}{TL^2}$ at either end; this analysis of the extreme value of stress due to the moment Pa is correct, if the straight edges of the base metal parts remain substantially straight while the weld is strained, and if the stress in the weld is proportional to the stress induced by the relative motion of the base metal parts. The stresses due to the vertical shear and the moment are at right angles, and the resultant intensity is the square root of the sum of their squares. If the weld is a fillet, the resultant should not exceed 11,300 lb. per square inch; if it is a butt weld, the resultant should not exceed 13,000 and the longitudinal shear alone should not exceed 11,300.

In Fig. 3b, the weld is eccentrically loaded by a transverse force, which may be resolved into a concentric force P and moment Pa. The concentric force induces unit stress $\frac{P}{TL}$ and the moment causes maximum stress $\frac{6\,Pa}{TL^2}$ at either end. The two parts of the stress are parallel, and at the end nearer the eccentrically applied load the resultant intensity is the arithmetic sum of the two components, while at the opposite end the resultant is the arithmetic difference. If the weld is a fillet, the larger intensity should not exceed 11,300. If it is a butt weld, and if the transverse stress is tension as indicated in the diagram, the larger intensity should be limited to 13,000; if the weld is a butt weld and the stress is compression, the larger stress should not exceed 15,000, and the smaller resultant, if tension, should not exceed 13,000.

Fillet welds should never be subjected to bending moments about their longitudinal axes, as they are not well adapted to resisting such stresses and are too small in throat section to have practical value for such purposes. Two parallel fillet welds, preferably an appreciable distance apart, may appropriately be used in combination to resist bending moments about the combined longitudinal axis, because the individual welds then act in transverse stress, not in bending stress.

It is essential for the engineer to understand certain precautions against excessive secondary bending stresses in the end connections of beams. If an end connection is not designed to accomplish fixation or continuity, and if the supporting member is rigid or is prevented from inclining, angular deflection of the end of the beam relatively to the supporting member occurs when the beam is loaded. Ordinarily, the angle of deflection is between .002 and .01, the average being probably about ½ per cent. The connection itself of part of the beam or of the support must yield, because anything approaching ½ per cent of angular deformation cannot occur within the yield point of the material. In Fig. 4, which is exaggerated as to angle of deflection, the connections are represented as being a pair of fillet welds at one end and a pair of welded side framing angles at the other. In the case of the direct welding, safety

against rupture is known to depend on making the welds heavy enough to deform the beam web without themselves reaching their yield point; this may be accomplished by making the size *D* of each weld not less than the thickness *W* of the web and the length *L* not more than half the beam depth; the size *D* must be the *net* size, which is the gross size less any gap existing between end of beam and face of support. In the case of the side framing angles, the flexibility of the angle legs is relied on to take care of the deflection, as in riveted connections of similar make-up. Generally, direct welding is unsuitable for beam connections, partly because of the variable space between cut end of beam and face of support, and partly on account of the secondary stresses which require special precautions. The most useful beam connections are seat angles, side framing angles, and combination connections designed for high bending

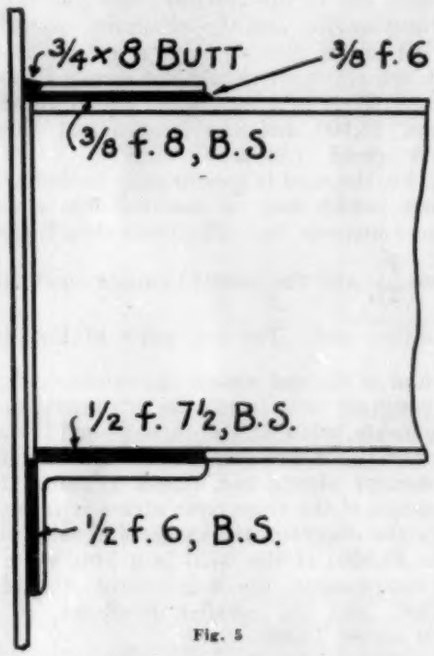


Fig. 5

strength and stiffness to accomplish continuity or resist severe wind stresses.

Assembled members are generally designed lighter for welding than for riveting. Welded roof trusses generally have few if any gusset plates, and its tension members require no allowance for rivet holes; welding saves 20 per cent to 30 per cent in weight of roof trusses. In very heavy trusses, such as are used to carry floors of buildings and sometimes multi-story columns in addition, welding does not eliminate gussets, but greatly reduces their size and weight, because far more stress can be transferred per square inch of gusset surface by welds than by rivets. Welded plate girders are made of plate material without angles; the effective depth is therefore a larger proportion of total depth than in a riveted girder; furthermore, no allowance need be made for rivet holes in tension flange; stiffeners are plates instead of angles and are therefore about half the weight of those used for riveting, and no fillers are needed between stiffeners and web. Not only are welded plate girders lighter than riveted ones, but they are stronger for a given section modulus because their compression flanges are additionally braced by being welded to the stiffeners. For wind bracing, welded beam-to-column connections are especially advantageous and provide 100 per cent bending strength and the limit of possible stiffness whenever required. Continuous beams are practicable with welding and are sometimes advantageous.

In computation notes and on drawings, welds should be indicated by the simplest possible drawing and notation. A heavy line on the detail drawing usually serves to indicate and locate a weld, and an adjacent note giving throat and length, in addition to an abbreviation to denote type of weld, describes it. In Fig. 5, each pair of fillet welds is shown by a heavy line and brief notation, as, for example, ½ f.6 B.S., which is intended to be read "half-inch fillet six inches long both sides." The butt weld at the top bar of this rigid beam connection is sufficiently described by ¾ × 8 *Butt* or some equally brief notation.

In the absence of opportunity to discuss design more comprehensively, a few miscellaneous comments may be useful.

(a) Fillet welds are used almost exclusively in welded buildings, butt welds being useful mainly for tension and compression bars at flanges of beams rigidly connected to columns. Fillet welds larger than ⅜ in. are not economical unless they save weight of connection material, because the rate at which metal may be deposited does not increase with additional size of weld, and the total volume of metal required to resist a given stress increases directly as the size. (b) In a building frame composed entirely of rolled beams, rolled columns and connections, the members are designed the same for welding as for riveting, except any beams which may be designed for continuity in the case of welding; the connections are usually somewhat lighter in the welded structure. In a building containing trusses, plate girders, cantilevers or other specialties, welding saves a substantial proportion of the weight of such parts. (c) Economy is far more dependent on skill in selecting connections in welded than in riveted construction. (d) The designer should always keep in view the methods to be employed for temporary security and for accuracy of spacing and plumbing of columns during erection; if erection bolts are to be used, they should be planned so as to require punching of as few main members as possible; clamps have been successfully used instead of bolts for erecting structures up to 100 ft. in height. (e) Welding overhead is slow and difficult, and should be avoided by designing connections so that the work can be performed downward or against vertical surfaces. (f) Drafting room and shop errors in dimensions are infrequent in welded construction because there are no holes to match; regardless of minor inaccuracies in fabrication, erection does not involve distorting connection members to make them fit. (g) Perfectly satisfactory welding can be done on clean flame-cut edges, without any element of imperfect bearing due to roughness of the surfaces. (h) Residual stresses due to shrinkage of weld metal in cooling do not ordinarily require attention in fillet welded connections, but butt welds to be used in tension should be made only when one of the parts joined is a loose connection piece which has not yet been welded to any other member. (i) The best way to deal with welding details on drawings is to show shop welding on the shop drawings and to show field welding on a separate set of small sheets to be used only by the welders in the field. It pays to standardize on a limited number of typical field connections for a given job, and to give each a serial number which may be marked on the erection plans alongside every joint to which it applies.

Code for Fusion Welding and Gas Cutting in Building Construction

Formulated by
American Welding Society
Committee on Building Codes

Code 1—Part A—Structural Steel

Edition of 1930

PREFACE
To 1928 Edition

The increase in the use of welding and gas cutting in the construction and equipment of buildings has brought to the American Welding Society a number of requests from municipal and other authorities for assistance in the formulation of regulations in the revision of existing Building Codes and the compilation of new codes where none is now in force, which will insure the safe and satisfactory use of the processes in the fabrication and erection of structural steel, piping and tankage in building construction.

In response to these requests a Committee on Building Codes was appointed by the President of the American Welding Society to undertake the codification of those practices in the application of fusion welding

and gas cutting in building construction which have reached the stage where they may be properly standardized.

Recommended practices in the application of fusion welding and gas cutting to structural steel have been prepared by the Committee and formulated in the accompanying Part A "American Welding Society Code for Fusion Welding and Gas Cutting of Structural Steel," which part has been formally approved by the Society. This document has been so arranged that it may be embodied wholly or in part in existing municipal or other Building Codes. Care has been taken to be conservative in the formulation of this code. The various regulations are based on practices which have been demonstrated to be safe by experience, covering many full size destructive tests and numerous welded building structures erected throughout the country.

This being the first edition of the Code, it has been made as simple and as devoid of details as possible. The Committee is prepared, however, to assist in the interpretation of the Code or its applications. Communications should be addressed to the American Welding Society, 33 West Thirty-ninth Street, New York City. The Society reserves the privilege of publishing inquiries and answers in its Journal, with the name of the inquirer omitted.

Codes dealing with fusion welding and gas cutting, as applied, respectively, to piping and tankage in buildings, are being prepared and will appear as Parts B and C. Other codes will be undertaken as the need for them arises. It is the purpose of these codes to serve and assist all interested in providing safe welded construction and to aid municipal and other authorities responsible for the preparation and enforcement of general building codes in the regulation of construction welding.

Following is the personnel of the Committee on Building Codes as at present constituted:

E. A. Doyle (Chairman)	The Linde Air Products Co.
J. L. Anderson	Air Reduction Sales Company.
Gilbert D. Fish	Westinghouse Electric & Manufacturing Co.
F. T. Llewellyn	U. S. Steel Corporation.
F. P. McKibben	General Electric Company.
H. H. Moss	The Linde Air Products Co.
James W. Owens	Newport News Shipbuilding & Dry Dock Co.
Edmund Vom Steeg	General Electric Company.

The Committee is authorized at all times to call for advice and assistance from responsible members of National Technical and Regulatory bodies in the work of preparing Welding Codes and the Committee proposes to enlist such aid as the needs arise.

F. T. LLEWELLYN, *President.*
American Welding Society.

PREFACE

To 1930 Edition

The 1930 Code includes an Appendix whose use obviates the necessity of consulting the publications of the American Bureau of Welding cited in the 1928 edition, and the body of the Code has been reworded to correspond. The matter given in the Appendix is primarily a digest of the publications referred to, with additional explanatory matter where needed to make it more applicable to Code purposes.

No other revision has been made in the body of the Code except in the wording of:

Sec. 3, Par.1—To limit the application of structural welding to a cited specification for base metal parts.

Sec. 4, Par. 1—To include a design criterion for fillet welds placed transverse to the direction of stress.

Sec. 5, Par. 5—To clarify the intention in this paragraph as regards beveling of butt joints which have only one edge beveled for welding, i.e. single bevel joints.

The publication of Codes for fusion welding will be supplemented by codes dealing with other welding processes which the Committee considers suitable when properly performed. As a part of this program it is now planning to compile a code covering electric resistance welding, as applied to the shop fabrication of building parts.

The following is the personnel of the Committee on Building Codes as constituted June 30th, 1930.

F. T. Llewellyn, Chairman	U. S. Steel Corporation
J. L. Anderson	Air Reduction Sales Company
H. G. Balcom	Consulting Engineer
C. T. Bissell	National Board of Fire Underwriters
Frank Burton	Steel Joist Institute
E. A. Doyle	The Linde Air Products Co.
G. D. Fish	Westinghouse Electric & Manufacturing Co.
Grover A. Hughes	Truscon Steel Co.
J. C. Lincoln	Lincoln Electric Company
F. P. McKibben	General Electric Company
H. H. Moss	The Linde Air Products Co.
James W. Owens	Welding Engineering and Research Corp.
Edmund Vom Steeg	General Electric Company
C. C. Whittier	R. W. Hunt Company
Herbert A. Woofter	Swift Electric Welder Co.

E. A. DOYLE, President,
American Welding Society.

Code for Fusion Welding and Gas Cutting in Building Construction

Part A—Structural Steel

SECTION 1. GENERAL APPLICATION

1. Fusion welding may be substituted for or used in combination with the riveting, bolting or other requirements already prescribed in the building code of the City of ————, hereinafter called the "Building Code", for connecting together, or assembling the component parts of, steel beams, girders, lintels, trusses, columns and other structural steel used in building construction; provided that the welding be done in accordance with Sections 3 to 7, inclusive, of this code.

2. Gas cutting may be substituted for shearing or sawing in the fabrication of structural steel members or parts, used in building construction, provided the cutting be done in accordance with Section 8 of this code.

SECTION 2. DEFINITIONS

The definitions of welding terms, as approved and published by the American Welding Society, shall govern for any welding terms appearing in this code.

For convenience, some of the more common terms have been included herein, and their specific applications under this code are defined as follows:

1. *Fusion Welding*—The process of joining metal parts in the molten, or molten and vapor states, without the application of mechanical pressure or blows.

Under this code, fusion welding is restricted to the arc and gas welding processes.

2. *Root*—The zone at the bottom of the cross-sectional space provided to contain a fusion weld.

3. *Throat*—The minimum thickness of a weld along a straight line passing through the root.

Under this code the throat of a fillet weld shall be the distance along a line from the root to the hypotenuse at right angles thereto, of the largest isosceles right triangle that can be constructed in the cross-section of the fillet weld; and the throat of a butt weld shall be equal to the thickness of the thinner part joined.

4. *Fillet Weld*—A weld of approximately triangular cross-section, whose throat lies in a plane disposed approximately 45 degrees with respect to the surfaces of the parts joined.

The *size of a fillet weld* shall be expressed in terms of the width in inches of its adjacent fused sides.

5. *Butt Weld*—A weld whose throat lies in a plane disposed approximately 90 degrees with respect to the surfaces of at least one of the parts joined.

The *size of a butt weld* shall be expressed in terms of its net or unreinforced throat dimension in inches.

6. *Weld Length*—The length of a weld shall be considered to be the unbroken length of the full cross-section of the weld exclusive of the length of any craters.

7. *Weld Dimensions*—Under this code the dimensions of a weld shall be expressed in terms of its size and length.

8. *Gas Cutting*—The process of severing ferrous metals by means of the chemical behavior of oxygen, in the presence of ferrous metals at high temperatures, to produce a kerf or cut of uniform width without burning the edges of the kerf or cut.

SECTION 3. MATERIALS

1. The grade of structural steel to be used under this code shall be that already prescribed in the Building Code, provided it conforms to the Standard Specifications of the American Society for Testing Materials for Structural Steel for Buildings, Serial Designation A-9, as amended to date.

2. The electrodes, welding wire and/or welding rods, shall either be one of the grades specified in the Appendix, page 10, Bulletin No. 2 or some equally good grade which, in the hands of an experienced welder, shows good weldability in flat, vertical and overhead positions. In the discretion of the Superintendent of Buildings it may be required to show the strength specified in the Appendix, page 11, Section "B".

SECTION 4. PERMISSIBLE UNIT STRESSES

1. Welded joints shall be proportioned so that the loads specified in the Building Code shall not cause stresses therein to exceed the following amounts in pounds per square inch:

Shear on section through throat of weld	11,300
Tension on section through throat of weld	13,000
Compression on section through throat of weld	15,000

Maximum fiber stresses due to bending shall not exceed the values prescribed above for tension and compression respectively.

Fillet welds placed transverse to the direction of stress shall be considered as under shear.

2. In designing welded joints adequate provision shall be made for bending stresses due to eccentricity, if any, in the disposition or section of base metal parts.

SECTION 5. DESIGN

1. The architect or engineer designing or supervising a welded structure shall be experienced and skilled in such work.

2. *Plate Girders*—Girders shall be proportioned either by their moments of inertia or by the flange area method. In applying the flange area method to welded girders having no holes in the web, one-sixth of the web area may be considered a part of each flange area.

Stiffeners may be either angles or flat bars, welded to the top and bottom flanges, and to the web, by continuous or intermittent fillet welds designed to transmit the stresses.

Connection of component parts of flanges to each other and of flanges to web shall be by continuous or intermittent fillet welds designed to transmit the stress.

3. *Beams*—The use of continuous beams and girders, designed in accordance with accepted engineering principles, shall be permitted provided that their welded connections be designed to transmit the stresses to which they may be subjected.

The connection at the ends of non-continuous beams shall be designed so as to avoid excessive secondary stresses due to bending.

4. *Columns*—Fillet welds connecting the component parts of a built-up column may be either continuous or intermittent. If intermittent, the length of each weld at the ends of the column shall be equal to the least width of the column. The length of the intervening welds shall be not less than 1½ inches, spaced not more than 4 inches in the clear. The size, length and spacing of the fillet welds shall be such as to provide the same strength, per unit of column length, as the rivets specified elsewhere in the Building Code.

Lattice bars and tie plates, if used, shall be welded so as to secure strengths equal to those of the rivets specified therefor elsewhere in the Building Code.

5. *Butt Joints*—One or both edges of base metal parts, ¼ inches or more in thickness, transmitting stress by means of butt welds shall be beveled. For single and double vee joints, the bevel of each part shall be not less than 30 deg., thus forming an open space with an angle of not less than 60 deg. For single and double bevel joints, the bevel shall be not less than 45 deg.

Before welding, the root edge or face of one part shall be separated from the root edge or face of the other part by the spacing given for butt joints in the Appendix, page 20, Section "E".

All butt welds shall be reinforced by depositing additional metal on the weld to a height extending beyond the surface of the thinnest part joined. The height of said reinforcement shall be not less than the following percentages of the thickness of the thinnest part joined:—20 per cent for single vee and single bevel butt welds, and 12½ per cent, on each side, for double vee and double bevel butt welds.

SECTION 6. WORKMANSHIP

1. Contractors for welded structures shall be required to satisfy the Superintendent of Buildings as to their ability to produce satisfactory welded joints of the forms specified, and with the process (arc or gas), materials and equipment to be used on the proposed work.

2. The quality of welds permitted under this code shall conform to the practice recommended in the Appendix, pages 11 to 20, Section "D".

3. Surfaces to be welded shall be free from loose mill scale, rust, paint or other foreign matter. A thin coat of linseed oil or equivalent, over the surfaces to be welded, need not be removed. This provision applies both in the case of new structures and where new steel is to be welded to steel in an existing structure.

4. In assembling and during welding, the component parts of a built-up member shall be held by sufficient clamps, or other adequate means, to hold the parts in proper relation for welding.

SECTION 7. ERECTION

1. Structural steel parts shall not be painted before they are welded. Parts that are welded in the shop, to be erected by bolts or rivets, shall receive the usual painting after the shop welding is finished. Parts to be field welded shall receive a coat of linseed oil after shop work is completed, and after erection and field welding, they shall receive as many coats of paint as the total number specified elsewhere in the Building Code for shop and field painting.

2. For all welded structures over 30 ft. in height, erection bolts, or equivalent means shall be employed for temporarily supporting the members and for insuring proper alignment.

SECTION 8. GAS CUTTING

1. The contractor shall be required to satisfy the Superintendent of Buildings as to his ability to produce satisfactory gas cuts.

2. Gas cut edges shall be smooth and regular in contour.

3. Gas cutting may be used in the preparation of base metal parts for welding, provided the edges so cut are thoroughly cleaned after cutting so as to expose clean steel.

4. Gas cutting shall not be permitted to replace the milling of surfaces specified elsewhere in the Building Code.

5. Gas cutting shall not be permitted on any member while it is carrying stress. This restriction shall not apply to detail cutting for the correction of minor fabricating errors, where the removal of metal resulting from such gas cutting would not reduce the required strength of the member that is to be cut.

6. Gas cutting of holes in a member which has not been designed therefor shall not be permitted.

APPENDIX

Digest of References to Publications of the American Bureau of Welding* in Code 1—Part A

BULLETIN No. 2

(Revised May 1st, 1921)

Specifications for Electrodes and Gas Welding Rods

(Cited in Paragraph 2, Section 3 of this Code)

Par. 3, pages 5 and 8—Material made by the puddling process is not permitted.

Par. 4, pages 5 and 8—Electrodes and gas welding rods shall be made of commercially straight wire of uniform homogeneous structure, free from irregularities in surface hardness, segregation, oxides, pipe, seams, or other harmful defects. Diameter shall not vary more than plus or minus 3 per cent from diameter specified.

Par. 5, pages 5 and 8—The prefix letter "E" is to indicate that the material is intended for arc welding and the prefix letter "G" for gas welding.

Par. 6, pages 5 and 8—The Chemical Composition of Iron and Steel Bare** electrodes for arc welding and of Iron and Steel plain or copper coated welding rods for gas welding shall be as follows:

For Electrodes Grade E—No. 1A and for Gas Welding Rods Grade G—No. 1A		Electrodes Grade E—No. 1B
Carbon	not over 0.06%	0.13 — 0.18%
Manganese	not over 0.15%	0.40 — 0.60%
Phosphorus	not over 0.04%	not over 0.04%
Sulphur	not over 0.04%	not over 0.04%
Silicon	not over 0.08%	not over 0.06%

Par. 9, pages 6 and 9—The surface of electrodes or welding rods shall be smooth and free from rust, oil, or grease.

*The American Bureau of Welding is an advisory board on welding research and standardization of the American Welding Society and the Division of Engineering of the National Research Council.

**Coated or covered electrodes conforming to the specifications for bare electrodes are recognized in Bulletin No. 2, but are not included among its definite recommendations.

STRUCTURAL STEEL WELDING COMMITTEE

Specifications for Test Specimens Their Preparation and Testing

July 1928

SECTION B

(Cited in Paragraph 2, Section 3 of this Code in connection with strength of welding wire)

Par. c and g—This test requires the welding of five (5) test plates similar to Fig. 1. Three of these plates shall be welded in a flat position, that is, the specimen is to be laid flat on a welding table or other suitable support. Two of these plates shall be welded in a vertical position, that is, the longitudinal axis of the joint is to be upright during welding.

The material for these test plates shall be open-hearth structural steel for buildings conforming to the latest A. S. T. M. specification A-9.

From each test plate, four (4) Standard American Welding Society Test Coupons shall be cut as shown in Fig. 2. The plain coupons, 18 in. long by 2 in. wide, shall be removed from the test plate by sawing or by cutting with a gas cutting torch. The coupons shall then be machined to the dimensions shown in Fig. 2, and any reinforcement of the weld above the base metal shall be removed by machining or grinding so that the thickness of the coupons at the weld shall not exceed the thickness of the base metal.

The average tensile strength per square inch of all the coupons shall not be less than 45,000 lb. if arc welded, or 52,000 lb. if gas welded, and the tensile strength per square inch of any one coupon shall not be less than 40,000 lb. if arc welded or 50,000 lb. if gas welded.

SECTION D

(Cited in Paragraph 2, Section 6 of this Code)

Quality of Welds

Section "D" explains a procedure for arc and gas welding under which sound welds are obtained. It also illustrates the conditions which ensue when this procedure is not followed. The essentials of this Section, given below, have been divided into three parts. 1—General Requirements; 2—Special Requirements for Arc Welds,* and 3—Special Requirements for Gas Welds.

GENERAL REQUIREMENTS

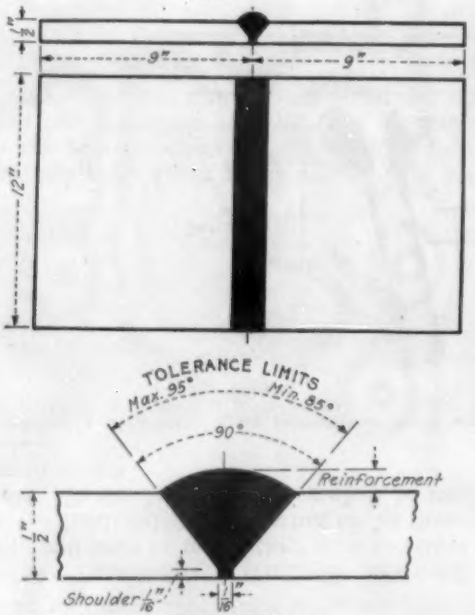
(1) *Soundness.* The weld metal shall be sound throughout and be free from excessive** oxides, non-metallic inclusions (slag), and gas pockets.

(2) *Penetration.* The weld metal shall penetrate into the root of the joint, as shown in (a) and (c) Fig. 3.

*The Special Requirements for Arc Welds apply to Direct Current Metal Arc Welding.

**Small plates or specks of oxides are not considered harmful if widely dispersed throughout the body of the weld.

FIG. 1



JOINT DETAIL FOR GAS WELDING

JOINT DETAIL FOR ARC WELDING

WELDING SPECIFICATIONS

Single "Vee" butt joint welded one side only.
Weld Penetration—100%.
Reinforcement—20% of plate thickness.

FOR ARC WELDING

Number of weld layers— 2
Amperes; average in flat position 200
In vertical position.175
Size of electrode....3/16"

Note—Before being welded the plates shall be tack welded at the ends of the joint.

FOR GAS WELDING

Method of welding, forward or backward.
Speed for ⅛" metal.
Flat welding—not less than 2 ft. per hr.
Vertical welding—not less than 1½ ft. per hr.
Width of finished weld—Not less than 2½ times plate thickness.

Note—Plates shall be clamped to a suitable table. The edges of the 1/16" shoulder at the end of the joint remote from that where the welding is started shall be spaced from 3/16" to 5/16" farther apart than is shown in the figure in order to compensate for contraction during welding.

FIG. 2

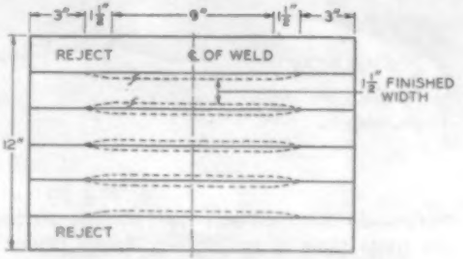


DIAGRAM OF TEST COUPONS

(3) *Fusion.* The weld metal shall be thoroughly fused with the base metal along all surfaces and edges of union. Uniform fusion with base metals of unequal thicknesses shall be obtained by playing the arc or flame a proportionally longer time upon the thicker material.

(4) *Contour.* The surface of welds shall be reasonably smooth and uniform in contour. In Arc Welding a crater is allowable at the terminus of weld. The crater will show depth of penetration.

(5) *Overlap.* The weld metal along the toe of the weld shall not overlap the base metal surface, but shall form an intimate contact therewith as illustrated and contrasted in (a), (b) and (c), (d) respectively of Fig. 4.

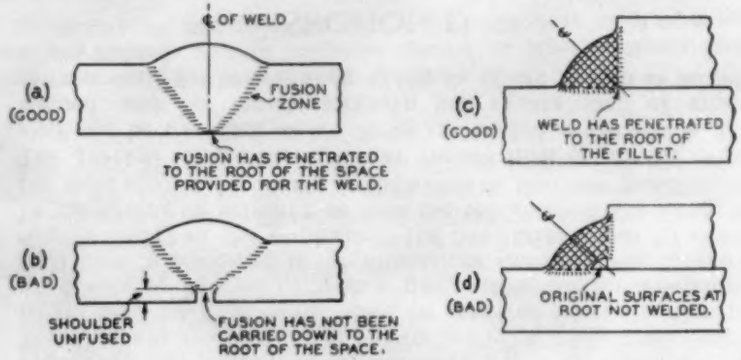


FIG. 3

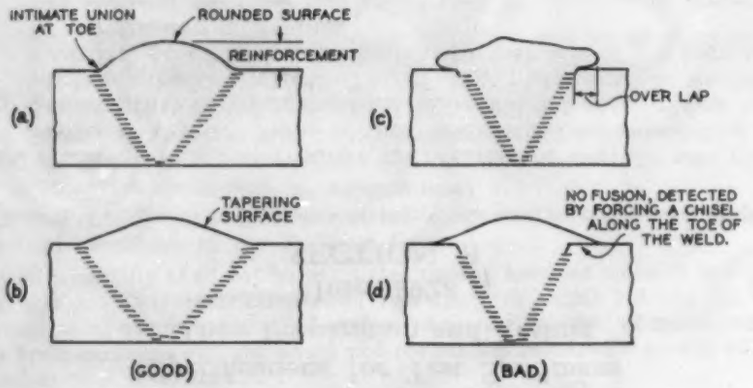


FIG. 4

(6) *Undercutting.* The base metal along the toe of a weld shall not be reduced in thickness (undercut or robbed) by the welding operation, as illustrated in (a), (b) and (c) of Fig. 5.

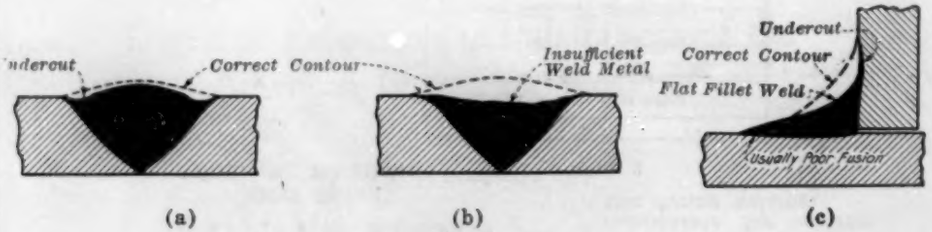


FIG. 5

(7) *Weld Ends.* The ends as well as the body of welds shall conform to the requirements of Paragraph (1).

(8) *Welfare.* While welding, the operator shall be protected from the rays of the arc or gas flame by suitable equipment provided for this purpose. He shall also be provided with facilities, whereby the process used may be carried on with comfort and efficiency.

(9) *Visibility.* The arrangement of the joints to be welded shall be such as to enable the welder to have an unobstructed view of the surfaces to be welded at all times during the welding operation.

(10) *Tack Welds*.* Whenever tack welds are located where a designed weld will later be made, they shall be either melted out when encountered in the final welding operation or be thoroughly fused-in with the final weld. In the latter case they shall be made according to the foregoing requirements.

*NOTE: A tack weld is an intermittent weld, usually about ½ in. in length, used for assembling structural parts in preparation for the designed welding.

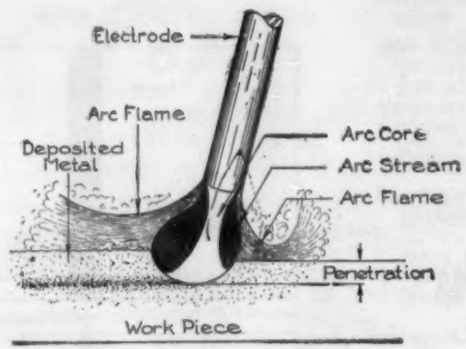


FIG. 6

SPECIAL REQUIREMENTS—ARC WELDS

Welding Arc. The characteristics of a direct current metal arc as used in welding are indicated in Fig. 6. Unsound welds, insufficient penetration and overlap in general, result from improper arc length and/or amount of current and/or incorrect rate of travel. The characteristics of these different conditions are illustrated in Fig. 7 and Fig. 8.

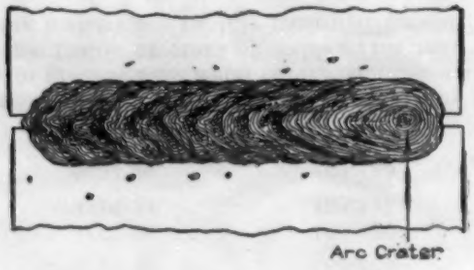


FIG. 7
Longitudinal section of deposited metal showing penetration and arc crater.

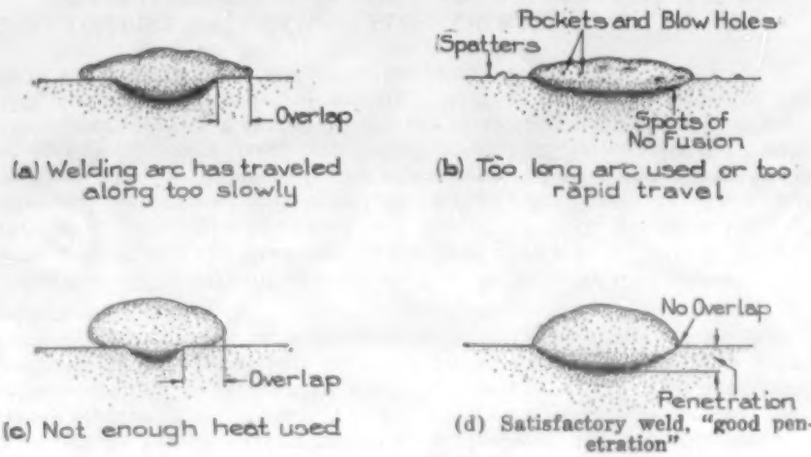


FIG. 8

Depth of Crater. The depth of arc crater should not be less than 1/16 in. See Fig. 7.

Length of Arc. In manual metal arc welding, proper fusion, penetration and soundness of weld shall be secured by using as short an arc as can be maintained for each form of weld. A typical example of proper arc length for given thicknesses of base metal and for a ⅜ in. fillet weld

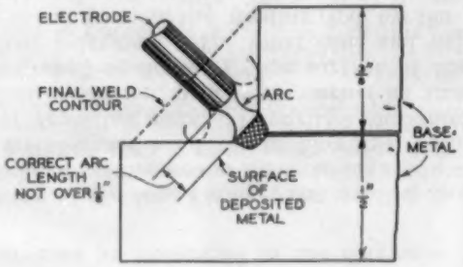


FIG. 9

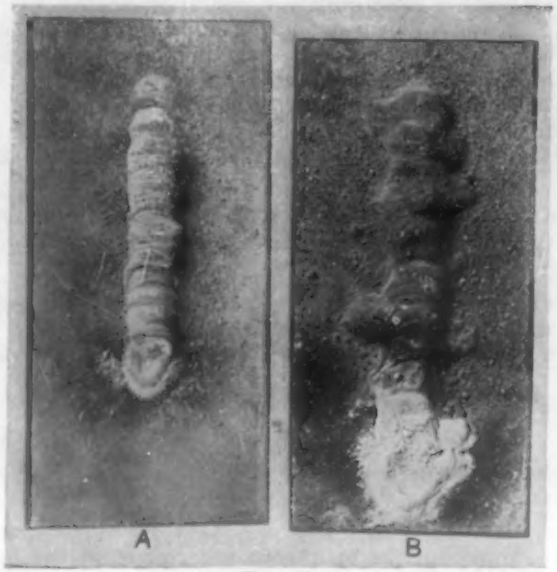


FIG. 10

A — Correct weld obtained with short arc. Note cleanness of surface

B — Incorrect weld obtained with long arc. Note heavy coatings of iron oxide

is shown in Fig. 9. When properly manipulated, the arc will throw a steady shower of small sparks, and (in the case of bare electrodes) will be accompanied by a regular, crackling, snappy sound with fractional intervals less than one-half second between explosions. With a given current, the length of arc depends upon the arc voltage which should seldom exceed 20 volts.

Current. The amount of current shall be such as will best suit the arrangement and the thickness of the base metals to be joined. It will vary with base metal thickness and size of electrode used. A table of sizes and current that have been found suitable for Structural Welding is given in Fig. 11. In special cases other approved sizes and currents may be specified. The current and voltage used shall be measured by suitable meters, either mounted on the arc welding machine panel, or portable, for use at the point of welding. Allowance shall be made for line drop where the meters are not adjacent to the point of welding.

CURRENT VALUES AND SIZES OF BARE AND LIGHTLY COATED ELECTRODES FOR VARIOUS SIZES OF WELDS

FIG. 11

Size of Weld	Size of Electrodes	Amperes	Layers
¼ in.	5/32 in.	160-180	1
	3/16 in.	180-225	
⅜ in.	5/32 in.	160-180	1
	3/16 in.	180-225	
½ in.	5/32 in.	160-180	2
	3/16 in.	180-225	
⅝ in.	5/32 in.	160-180	2
	3/16 in.	180-225	
¾ in.	5/32 in.	160-180	3
	3/16 in.	180-225	

Manual Operation of Arc. The arc shall be started by drawing a long arc momentarily to preheat base metal before deposition of filler material to insure thorough fusion at start of weld. This may also be accomplished by moving a short arc rapidly back and forward over a limited area at start.

In case of a long weld where more than one electrode is used, the arc shall be re-started about ¼ in. to ⅜ in. ahead of the crater, going back over the crater to properly fill it and keep a uniform contour, thus insuring proper preheating as in start of weld.

On single layer welds the arc may progress with either a straight forward motion or an oscillatory motion depending on size of joint to be filled to bring it up to proper contour and insure proper fusion in root zone.

In multi-layer welding the first layer shall be deposited by moving the arc in a straight forward motion to secure proper fusion in the root zone, while subsequent layers shall be deposited with an oscillatory motion to build up the weld to the proper contour. The first layer shall be made with an electrode small enough to get thorough penetration at the root zone.

Each layer shall be thoroughly cleaned by brushing or chipping to remove all excess scale and oxides before depositing succeeding layers. The surface of each layer shall be reasonably smooth and uniform in contour.

SPECIAL REQUIREMENTS—GAS WELDS

Welding Flame. The characteristics of a welding flame are indicated in Fig. 12. The maintenance of a well defined neutral inner cone is the most important feature. Its shape and length are dependent upon the gas pressure and the size and cleanliness of the orifice of the welding tip.

Welding Tip. The orifice of the welding tip shall be kept clean at all times during the welding operation so that a regular and rounded inner cone similar to the diagrams (1) and (2) of Fig. 12 can be maintained.

Size of Inner Cone. The size of the inner cone shall be regulated for varying thicknesses of base metal so that the proper amount of heat is obtained to perform the welding operation. The criterion for welding flame regulation is a neutral inner cone, the size of which produces sufficient heat to maintain the surfaces of base or base and deposited metal within the local zone of welding in a quiet molten state*.

Gas Pressure. When applied to different types of torches or blowpipes and varying lengths of gas hose, the gas pressure for oxygen and acetylene shall be such as to produce and maintain a soft and regular rounded end neutral inner cone as illustrated in the diagrams (1) and (2) of Fig. 12.

Manual Operation of Welding Flame. The welding flame (inner cone) should be manipulated by the welder so as to maintain a definite puddle of molten weld metal under his torch or blowpipe, without overheating either the base or deposited metal. Impurities encountered or produced during the welding operation, usually appearing as small white specks, globules or plates, shall be floated to the surface of the weld metal by melting below their lodgement. The inner cone and welding rod should be manipulated so as to melt the welding rod by the radiant heat of the inner cone rather than directly by the inner cone. Welds joining base metal parts of even thicknesses, provided their arrangement is such as to provide equal rates of radiation, shall be made with a regular oscillation of the welding flame.

Multi-layer Welding. Welds having a throat dimension of 7/16 in. or less are usually made in one layer or pass. Where the throat dimen-

*This condition is generally obtained by moving or oscillating the flame within the local zone, the rate of motion or oscillation being sufficient to maintain the local zone in the proper molten state.

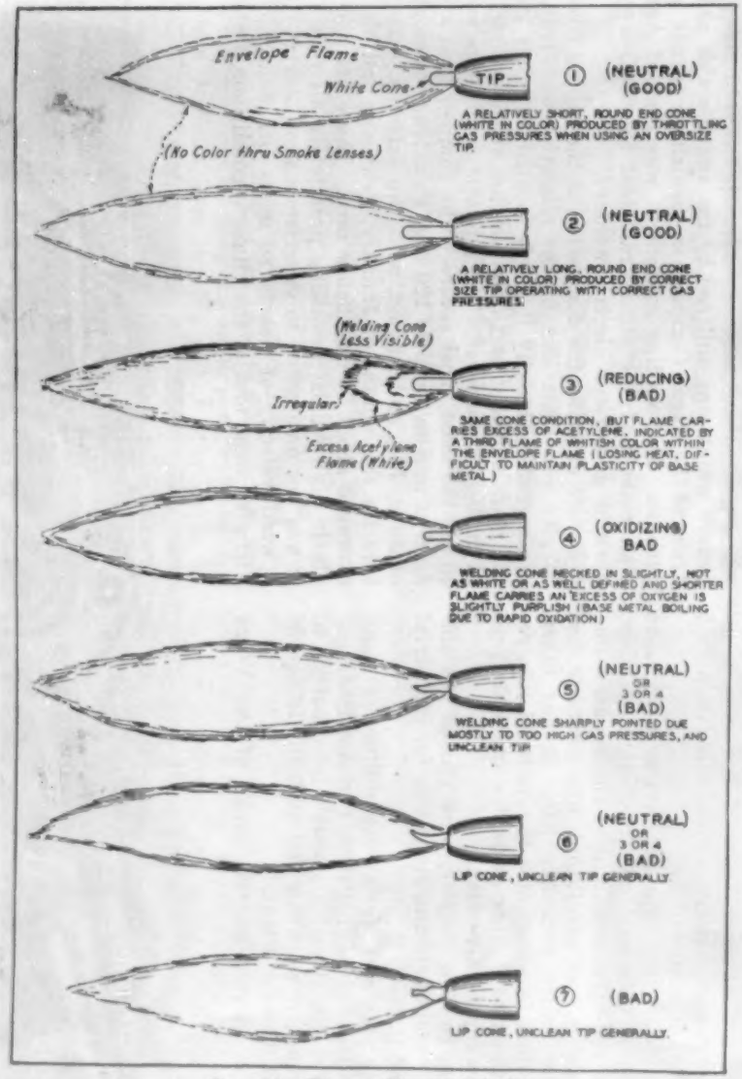

Envelope Flame
White Cone
TIP
(No Color thru Smoke Lenses)
(Welding Cone Less Visible)
Irregular
Excess Acetylene Flame (White)
① (NEUTRAL) (GOOD)
A RELATIVELY SHORT, ROUND END CONE (WHITE IN COLOR) PRODUCED BY THROTTLING GAS PRESSURES WHEN USING AN OVERSIZE TIP.
② (NEUTRAL) (GOOD)
A RELATIVELY LONG, ROUND END CONE (WHITE IN COLOR) PRODUCED BY CORRECT SIZE TIP OPERATING WITH CORRECT GAS PRESSURES.
③ (REDUCING) (BAD)
SAME CONE CONDITION, BUT FLAME CARRIES EXCESS OF ACETYLENE, INDICATED BY A THIRD FLAME OF WHITISH COLOR WITHIN THE ENVELOPE FLAME (LOSING HEAT, DIFFICULT TO MAINTAIN PLASTICITY OF BASE METAL.)
④ (OXIDIZING) BAD
WELDING CONE NECKED IN SLIGHTLY, NOT AS WHITE OR AS WELL DEFINED AND SHORTER FLAME CARRIES AN EXCESS OF OXYGEN IS SLIGHTLY PURPLISH (BASE METAL BOILING DUE TO RAPID OXIDATION)
⑤ (NEUTRAL) OR 3 OR 4 (BAD)
WELDING CONE SHARPLY POINTED DUE MOSTLY TO TOO HIGH GAS PRESSURES, AND UNCLEAN TIP
⑥ (NEUTRAL) OR 3 OR 4 (BAD)
LIP CONE, UNCLEAN TIP GENERALLY
⑦ (BAD)
LIP CONE, UNCLEAN TIP GENERALLY.

FIG. 12—Flame Characteristics

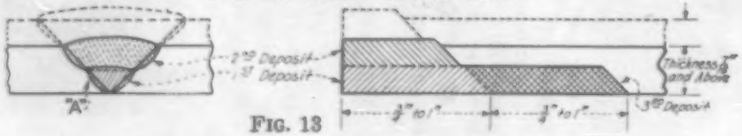


FIG. 13

sion is greater than 7/16 in., a preliminary light deposit of weld metal should be made in the root zone, upon which the final deposit of one or more layers is superimposed, as shown in Fig. 13.

SECTION E

Design of Test Specimens

(Cited in Paragraph 5, Section 5 of this Code)

Pages 22 *to* 28, *Spacing for Butt Welds**

*The essence of the requirement is that there shall be a small space between the root edges or shoulders at the bottom of a Vee joint. In arc welding the aim should be to keep this space 3/16 in. wide. In gas welding the aim should be to keep this space 1/16 in. wide when throat is 1/2 in. or less, 1/8 in. when throat is between 1/2 and 1 in. and 3/16 in. when throat is 1 in. or more.

Welding and Fabrication of Industrial Pipe

By W. J. THOMAS

✦ This paper was presented at the December 18th meeting, Detroit Section, A. W. S., by W. J. Thomas, of Walter J. Thomas & Co.

RUSSIA, within recent years, has been very much in the world's public eye. At first it was the outbreak of the revolution and probable effect on the World War. Then followed the spectacular succession of political régimes. And now the unprecedented industrial expansion of the country makes us take cognizance of that mysterious land.

I am often asked just what is happening in Russia? What is the five-year plan? How does the Russian Government go about solving its problem? How are its religious conditions? Why the foreign specialist is called upon. The conditions of the people and living conditions.

I shall try to answer some of these many questions, but first I must give a bird's-eye view of that country and her immediate problems.

A glance at the map brings out the fact that Russia, or U. S. S. R. (United Socialist Soviet Republic) occupies an area equal to about one-sixth of the combined areas of all continents. Her climatic conditions vary through all gradations, from mild Crimea to severe Siberia.

The natural resources consist of grain, wool, oil, coal, gold, silver, iron, copper, aluminum, nickel, lumber, fish, fruit, garden and dairy products.

The population is about 150,000,000 and is made up of more different and distinct nationalities than that of any other country on earth.

There are about 700,000 persons in the present party controlling this vast country, since October, 1917. At this time the condition of the country, due to war and famine, and revolution, was complete disruption to the entire economic life. It has taken superhuman effort to reorganize the national life, reestablish relations with other countries and make preliminary plans for resurrection.

Albert Kahn, Inc., of Detroit, were chosen the official consulting architects and engineers for industrial development of U. S. S. R.

The five-year plan calls for an expenditure of many millions of dollars. In June, 1929, two American engineers left for Russia with enough information to start the foundation work for the main buildings of the Stalingrad Tractor Plant.

Stalingrad is located on the banks of the Volga River, about 650 miles southeast of Moscow, and about 225 miles northwest of the Caspian Sea.

About six weeks later four more Americans followed with completed plans for these buildings. These six men comprised a general construction superintendent, three assistant superintendents, one superintendent of welding and the architect's representative.

At first the foreign specialists who were anxious to get started and show American speed in construction and their Soviet assistants who were very anxious to learn and follow suit, experienced some difficulty in understanding each other. The interpreters, who were, as a rule, not acquainted with the proper terminology, had a difficult task in bringing them together. After some time, however, both sides learned enough key words in the other language to convey the meaning—I would say "pipe" and the Russian—"truba" or "rod"—and the Russian "probica," "welding" for "swocka." After the first three months it was a rare thing to see an interpreter trailing after an American engineer on the site of the growing plant.

My first task was to obtain oxygen, acetylene generators, carbide and welding equipment and to train welders. For the first few months it was necessary to run a welding school and with the assistance of Ragas, the Russian Oxygen Manufacturers of Moscow, we were able to get a sufficient number of men and women to attend this school, and after this training we were able to develop eighty-one competent welders. Then we established a regular welding shop where the entire piping system was fabricated in its entirety, long before the buildings were erected and ready for the pipe. If this had not been done the tractor plant would never have been ready to operate on the date that the Soviet officials had set for its completion. I arrived in Stalingrad Aug. 15, 1929, and the plant was completed and the first tractor finished and off the assembly line June 21, 1930.

I can only say that this was accomplished by the wholeheartedness that the welders followed the procedure which was outlined by me and the able assistance of the Ragas Company in furnishing oxygen and carbide. The welding equipment was that of American make and the structural steel fabrication was done by gas-driven electric welders.

Before entering the discussion of the piping I want to give you some idea of the climatic conditions at Stalingrad. The city itself is located 12 miles from the plant and that particular section of the country is 27 ft. below sea level. The climatic conditions were, to say the least, most severe. The summer heat averaged at mid-day, nearly 120 deg. Fahr. for the months of June, July and August, while an extreme temperature for the months of January, February and March averaged about 30 deg. below zero. There are particularly high winds prevailing practically all year and it was not uncommon to experience sand storms with a wind velocity of nearly 80 miles per hour. This will give some idea of the climatic conditions prevail-

Fig. 1—General View of Buildings

ing so that you will appreciate the handicap under which the plant was constructed.

The plant was designed and built to produce tractors similar in type to the small tractor built by the International Harvester Company and the plant is supposed to have a capacity of about 20,000 tractors per year. When the engineers from Albert Kahn, Inc., arrived on the scene the ground now covered by the plant was unbroken and approximately ten months later the first tractor was completed.

The plant itself consists primarily of the power house, which is equipped with high-pressure combustion engineering boilers carrying steam at 750 lb. The turbines were furnished by Westinghouse Electric & Manufacturing Company to produce 150,000 kw. of load. The power house building was approximately 200 by 300 ft. in size. The main assembly building was 1,400 ft. long by 350 ft. wide. The gray-iron foundry was a building 650 ft. long and 600 ft. wide. The forge shop is a "U" shaped building with a base 750 ft. long and the length approximately 350

Fig. 2—View in Main Tunnel

ft. The tool repair building is 550 ft. long by 225 ft. wide. The machine repair building is 400 ft. long by 200 ft. wide. In addition to the factory buildings above described there are 500 buildings built for the housing of employees, as well as an administration building for the factory itself. The panorama of the plant was taken from the roof of the administration building and practically none of the buildings for housing the employees are shown in the picture. There is one of these buildings shown at the extreme right-hand corner of the panorama.

We, of course, are interested primarily in the welding that was carried on in the construction of this plant and the buildings housing the employees. At the outset I want to say that every joint that it was possible to weld in all of the lines in this plant as well as in he buildings housing the employees, were welded and this includes pipe ranging in size from ½ in. to 24 in. There were somewhat over 362,000 welds made in the installation of the piping of this institution. Quite naturally some may think this an exaggeration, but when we tell you that we had to fabricate and make all of the radiators by the welding process, that we welded all of the conduits and even all of the mains, all of the compressed air and all water lines, all oil lines and the complete heating system, all mains carrying live steam for plant operation as well as all piping connections to working machines, hammers, etc., you can probably realize that the number of welds above mentioned is probably a conservative figure. Furthermore, this figure can be substantiated by the fact that all of this work was done on a piece work system and each welder was required to report each day the number of welds that had been made and the officials of the Soviet Government inspected and counted the number of welds made and reported by each operator.

There were approximately 20,000 tube turns used in the piping system for these various buildings. As tube turns larger than 14 in. could not be obtained all fittings for change of direction in pipes larger

Fig. 3—Welded 24 In. Elbows

than 14 in. were fabricated. We might state that there was a very novel use made of tube turns in this installation in that they were used for making expansion loops. There were no facilities available for making the ordinary large expansion loops, and consequently, these loops were made by the use of 90 deg. tube turns and all of these expansion loops proved entirely satisfactory. The largest Armstrong Stock and Die Equipment that was used in the piping installation was 4 in. Where it was necessary to use a thread, threads were cut from the end of the pipe and rewelded to the blank end of other pipe in order to give us threads for valve connections, etc. There was no pipe threading equipment of any kind on this job as it was not available. The welding torch was the only tool that made the installation of this piping system possible. The most important feature of the whole job was the fact that because there was no prejudice against the process of welding, it was accepted at its face value and as a consequence the work progressed very very rapidly.

When I arrived on the scene there was absolutely

no one among the native Russians at that time on hand who had ever seen an oxy-acetylene torch or an electric arc welder. In three months' time, out of over 400 applicants a crew of 83 welders was organized. This crew of 83, including five women, who did all of the welding on the installation. It was found that the 83 who were finally accepted as welders, picked up the art very rapidly, and this was due primarily to the fact that they were forced to follow instructions very carefully. All of the piping in this plant was tested at 200 lb. hydrostatic pressure under the supervision of the Russian Government commission, composed of men from their safety board who were, for the most part, graduates from either the Russian or German technical schools. These men, it must be realized, are very competent engineers. In the entire system which was welded there were 91 leaks found on test and this will give you an idea of the skill of these welders, and it further indicates that with intensive training under the supervision of competent instructors, that welders can be taught how to make a proper joint. All of the 83 welders

Fig. 4—View of Generator Used and Some of the Overhead Piping

would not be considered expert welders, but they were able to make proper joints under direct supervision.

Naturally some might think that the number of welds made in approximately seven months' time would be out of the question, but it must be remembered that in the welding department all of the operators worked seven days a week and the work progressed 24 hours a day. In other words, the crew was split up in four six-hour shifts and in the entire seven months the welding of the lines never ceased for a moment. Furthermore, a great deal of the pipe was fabricated prior to the erection of the building. This was accomplished by welding the layout, as shown on the drawings, as far as possible, marking these welded sections in such a manner that they could be installed in large sections after the plant was far enough advanced to permit their installation.

There was a tunnel leading from the power house through the assembly buildings underneath the entire plant, to an oil storage tank pond located to the right of the building shown in the panorama view. This tunnel contained two 8-in. lines and four 6-in. lines. In addition, there was a tunnel from the power house up to the building housing the employees, which was a mile and a half in length. This tunnel carried all the following mains:

2—24″ lines at the power house terminating at the end of the tunnel in 14″ lines.
1—20″ high pressure line terminating in a 6″ high pressure line.
1—14″ water line running the entire length.
2—6″ oil lines carried the entire length.
1—12″ compressed air line carried the entire length under the plant.
1—8″ filtered water line.
1—10″ high pressure return line.
1—24″ hot water return line.

Fig. 2 shows the main tunnel showing the 24-in. line together with the smaller lines. At the time this photograph was taken all of the lines were not yet installed. All of the pipe racks were fabricated by the acetylene torch and the electric arc.

Fig. 3 shows 24-in. elbow which was fabricated, this being necessary on account of the fact that tube turns of this size were not available. A small 2-in. tube turn is shown in the photograph.

Fig. 4. shows the rather crude generator used, as well as the old type oxygen cylinders. These cylinders were practically 6 ft. high and weighed over 200 lb. We want to bring out the difficulty experienced in the operation of the generators, particularly during the severe weather. In order to use them at all it was necessary that we house them in a sheet iron house, which was portable and a wood-burning salamander 10 ft. away, with the exhaust heat from this salamander carried through a 6-in. pipe leading through the sheet iron house surrounding the generator. The heat from the pipe passing through the sheet iron house surrounding the generator was necessary to keep the generators from freezing. This had to be carried on during the winter months. These generators are all water to carbide feed and great difficulty was experienced with wet acetylene. American-made welding and cutting torches as well as regulators were used entirely on the job.

In closing we again impress upon you the magnitude of this job, and all of the pipe that was welded was done with oxy-acetylene torch, which made it possible to complete this job on contract time to the entire satisfaction of the Russian officials.

These photographs which you have seen were taken out of Russia only with a special permit granted by the Supreme Council of the Russian Government.

Experiments on Gas Welded Structural Joints

By JAMES R. GRIFFITH

✦ This paper was presented by James R. Griffith, Professor of Structural Engineering, Oregon State College, before the 31st annual convention—International Acetylene Association, Chicago, Illinois—November, 1930.

STRUCTURAL welding has had a tremendous growth in the past year. So it gives me much pleasure to describe the work being done on welded structural connections at our college.

Institutions such as Oregon State College have many problems of education outside of regular class room work. Welding, as now practiced, is relatively new. In order to assist in the education of the public, a second welding conference was promoted at the college in February, 1930. George B. Cox, professor of industrial arts, was in charge. His untiring spirit and encouragement contributed to a large degree to the success of the experimental work.

I was asked to prepare a paper raising some of the pertinent questions in the application of welding to the structural engineering field. While preparing the paper, I raised many questions for which no answer could be found. So it was decided to try and answer some of the questions by what limited research we could do with the funds available. Little was it realized what we were getting into. The questions are still coming up at an alarmingly rapid rate. Each answer seems to originate many questions.

It fell to my lot to design the test specimens and put the wheels in motion. Commercial organizations co-operated in the preparation of many of the test specimens. The rest were prepared in the school forge shop.

The college forge shop is very well equipped to do gas welding and has been giving instructional work in it for 2 years. Ten welding stations are supplied by a standard 300-pound acetylene generator. William H. Horning, instructor in forging, is in charge of this work and is doing some remarkable ornamental welding. He is not only a master of the art himself, but is able to teach others. Each student chooses a project, usually some ornamental work which he can take home and use. He is charged only for the actual materials used. As a consequence, little structural welding is being taught.

Last year, one of my senior students found a new application for welding wire. He fabricated a model of a mill-bent from welding wire and used it to analyze the reactions from wind loads. His paper on the subject won a prize offered by the Portland section of the American Society of Civil Engineers.

When the various structural test specimens were fabricated, they were sent to the college material testing laboratory. J. C. Othus, assistant professor of mechanics and materials, was in charge of this phase of the work. Professor Othus, assisted by Clarence Robinson, senior in the school of civil engineering, did all the actual testing.

A few days before the opening of the welding conference, I became interested in the subject of nondestructive tests of welds. One of my senior students, John Reiff, was put to work on the problem. This fall the experiments are being continued by R. G. Robley, senior in civil engineering, and J. R. Batcheller, senior in electrical engineering. A. L. Albert, assistant professor of electrical engineering, has given us much help and advice in doing some of the things I will later demonstrate.

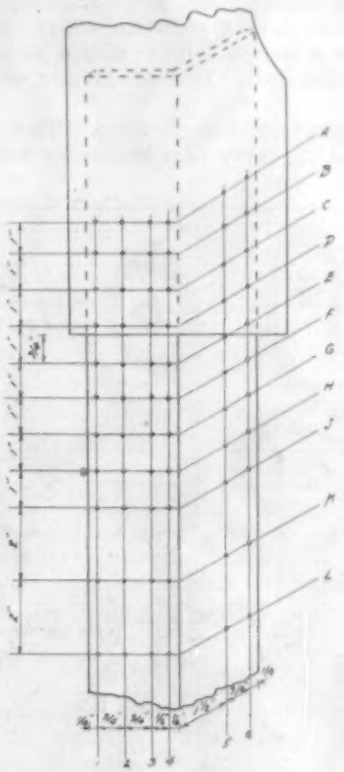


Fig. 1—Location on System of Numbering Gage Stations

TABLE I—COMPARATIVE EFFICIENCY OF AMATEUR AND PROFESSIONAL GAS WELDS

Specimen No.	1	2	3	4	5	6	7	8	9	Ave.
Professional	100.0	100.0	100.0	98.5	98.5	100.0	...	...	...	99.5%
Amateur	100.0	90.0	100.0	99.0	99.0	99.8	90.7	100.0	96.0	97.1%

$$\text{Efficiency} = \frac{\text{Ultimate load to break specimen}}{\text{Computed strength of member}}$$

TABLE II—READINGS ALONG STATION LINE (L) HALF WAY BETWEEN CONNECTIONS

UNIT STRESS IN THOUSAND-POUNDS PER SQUARE INCH

Load, Lbs.	Riveted One Leg			Riveted Lug Angle			Welded One Leg			Welded Lug Angle		
	1	4	6*	1	4	6*	1	4	6*	1	4	6*
20,750	33.9	30.5	20.0	38.7	35.0	16.9	20.4	A	15.1	...	..	...
25,300	A	36.7	24.0	A	A	18.8	23.7	A	22.5	...	..	...
31,200	...	...	...	...	...	...	23.4	A	32.4	23.7	A	17.9

A—Indicates stress above yield point.
*Indicates compression. All other values are in tension.
Total load, 18,000 lbs. per sq. in. on net section = 25,300 lbs.
Total load, reduced for eccentricity, 82% of 25,300 = 20,750 lbs.
Total load, 18,000 lbs. per sq. in. on gross section = 31,200 lbs.

The first question to be raised was: *How much does the strength of a gas weld depend upon the skill and experience of the operator?* Plenty of amateur welders were available among Mr. Horning's students. They prepared test specimens. Several commercial organi-

zations prepared similar specimens to be used for comparison.

These specimens, consisting of welded plates, were sawed into one-inch strips for convenience in testing. The actual area in each piece was measured, and then broken in tension. I have shown the tabular results in Table I. We were more than gratified by the results. Structural engineers have come to look with confidence upon riveted connections. If amateurs, picked at random, can make such a showing, why worry about the reliability of a welded joint? Rolled structural shapes vary more than this. Few stress computations are as accurate.

Another question then came up. *What is the learning, or efficiency, curve of a beginning welder?* If, for

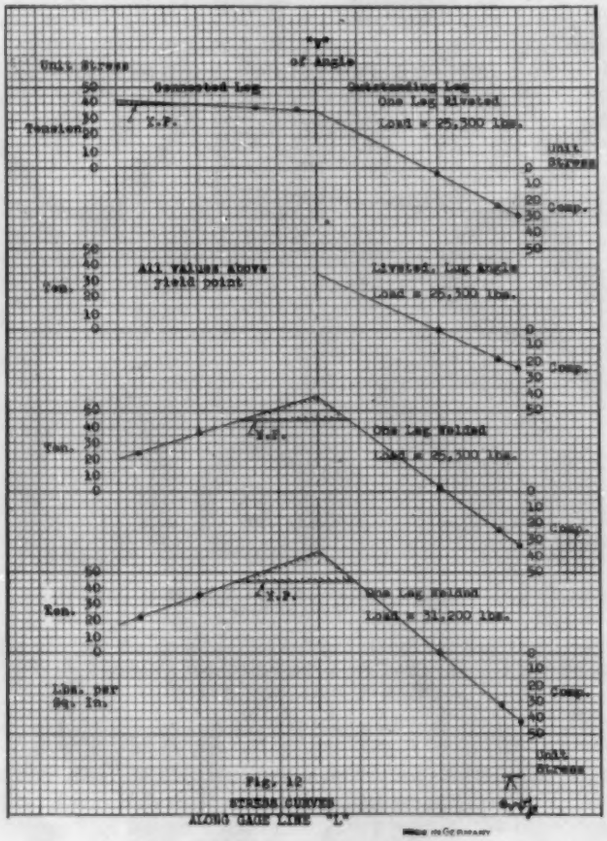


Fig. 2—Stress Curves Along Gauge Line "L"

instance, an individual without previous experience or knowledge was told how to make a gas weld, and then permitted to make one. What would be the efficiency of the joint? Then at hourly intervals of experience, if samples were made and tested, what improvement would be shown? How fast will his efficiency curve climb? How many hours before he can attain 100 per cent efficiency, or make a weld as strong as the member? Beyond that point, little is to be gained except speed. Interesting possibilities I know. But so far we have had neither the time nor finances to do it.

The next question to arise was: *How do welded structural connections compare with riveted?* I had been giving some thought to standard methods of riveting connections, and could think of many points for comparison with welded connections.

When connecting a single leg of an angle to a gusset plate with rivets, flexural stresses are set up upon application of a load. The flexural stresses are due to the eccentricity of the connection. I can best demonstrate the effect of an eccentric load by the use of a steel band, or spline. The spline was connected at each end to wooden blocks. Pins were inserted off center from the spline by a distance (e). Now, if a pull is exerted by way of the pins, a bending moment is induced, by the eccentricity (e) and the load, equivalent in magnitude to $M = P\ e$. The bending moment sets up flexural stresses of tension and compression, indicated by the bent spline. It will be noted that the central portion of the spline seeks to attain the line of the pull. Nature tries to remove the eccentricity.

When the leg of an angle is riveted to a gusset plate, the connection does not coincide with the center of gravity of the angle. The connection is eccentric. As a load is applied, flexural stresses are set up in both legs. Some authorities have recognized this fact and reduced the allowable load. But just how serious is it?

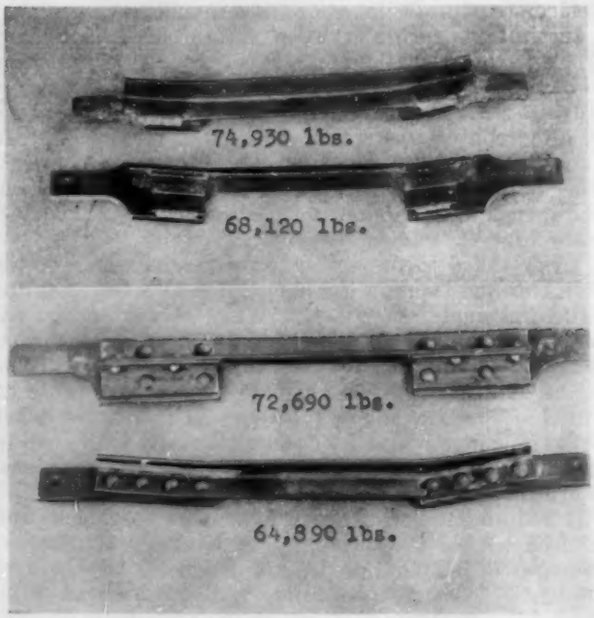


Fig. 3—Specimens After Failure

I am afraid most designers have made just a guess. Some authorities consider the use of a lug angle as removing this objectionable eccentricity. Others claim it is of no value.

If this condition exists in riveted connections, is it to be found in welded connections? Theoretically, the eccentricity could be avoided in one leg by the proper distribution of the weld, but did it actually do this? Would the use of a lug angle remove the eccentricity in the outstanding leg? I could find no answers. Previous tests had been on short length members. Experimenters had been more interested in the strength of the weld than the stresses set up in the member itself.

In order to allow for the longest possible length of angle which the testing machine would take, we were practically limited to the use of a 2½ x 2½ x ⅜ inch angle. The connection was made at each end by means of two bars so as to eliminate all possibility of torsional stresses from the testing machine.

It might be well to mention how the unit stress was determined at the various locations. As a load is applied to a steel member, up to a certain point called the

yield point, unit deformation is proportional to unit stress. This ratio, called the modulus of elasticity, can be accurately determined. If the ratio is known, and the unit deformation (stretch) is determined, the unit stress can be computed. The Berry strain gage was used to determine the unit deformation.

So-called gage stations had been laid out along the angle before it was put into the testing machine. I have shown the system of designation and location of the various gage stations, for I shall have occasion to refer to certain stations. (Fig. 1.)

To give all the tabular results would mean little to most of you. They would but add to the confusion. So I have tried to make comparisons in such a way that general results can be seen without so much confusion as to hide the facts. (See Table II.)

Readings were taken over the entire angle and connection. As was expected, the intensity of stress increased from the connection to station line (L) half way between connections. I have given critical values along this station line (L). Station (1) was close to the edge of the connected leg. Station (4) was close to the (V) of the angle. Station (6) was close to the edge of the outstanding leg.

In making a comparison, please remember that the various loads applied were determined by customary methods of computation. In each case, the intention was to have the unit stress not exceed 18,000 lb. per sq. in.

I regret that the tests are not as complete as I would prefer. Perhaps in the future we may find financial means by which to carry the research to more complete results. However, for the tests made, the results were surprising to all of us.

When the yield point was exceeded, the strain gage reading did not give the actual stress. At these points, no value is tabulated. So I have tried to show in Fig. 2 how seriously the yield point was exceeded by plotting stress curves along station line (L). Assuming straight line variation, lines were drawn through the plotted points giving some idea of the stress beyond the yield point. Strictly speaking, these curves more nearly represent the deformation. Beyond the yield point, unit stress is not proportional to unit deformation. So the actual stress is somewhat below the limit shown in the cross hatched portion. The curves at least permit of comparison between joints.

The results would seem to indicate that, for the working load, the stress distribution of the welded joint is little, if at all, better than for the riveted joint. Of course it must be remembered that the unit stress at the minimum section of the riveted connection has not been shown. And this section is the weak point.

The welded connection seems to indicate more eccentricity in the plane of the connected leg than the riveted member. I have been questioning, in my own mind, the present method of figuring the weld distribution for the angle connection. I am not so sure it cannot be improved. But this demands research, and so far we have not had the funds with which to try it.

Let it be understood that it is a real problem to obtain money for engineering research in a state agricultural college. This is especially true in a state where agricultural interests predominate.

When tested to final destruction, the gas welded specimens, as was to be expected, made a much better showing than the riveted ones. I have shown photographs of the broken specimens. The load indicated under each member is the actual load required to break it.

The strength of any weld depends largely upon the skill and care of the operator. Material may be carefully standardized. But if the right heat is not applied, the best of materials are of little use. I note that in some recent welded structures, the operators were required to pass periodic examinations on their ability to make satisfactory welds. Any operator who could pass the first test, could surely pass any others. And he would be foolish to not put his best efforts into the test weld. But what will he do on the actual structure? Understand, this is no criticism of welding operators alone. It is more a criticism of human nature. I have been on too many construction jobs to not realize that the best workman is careless at times. How are these careless welds to be located?

In the January, 1930, issue of *Oxy-Acetylene Tips*, an article described how welds might be tested by using a doctor's stethoscope. I obtained a stethoscope and began to make myself obnoxious to the other occupants of the building with my tapping. I then conceived the idea of demonstrating the method to the welding conference. To let each member listen with the stethoscope was out of the question. So, with the help of the electrical engineering department, we set up an amplifier and loud speaker. The sounds were magnified so all the audience could hear it. At the present writing, we are still tapping—but with an amplification that sometimes resembles the din of a boiler shop. But one question leads to another. We are still searching, and expect to continue for some time if we are not thrown out for disturbing the peace.

Welded Barge

MR. G. MITTON of El Higo, Mexico, has recently sent to the Society some interesting photographs concerning the construction of an all welded barge 59 ft. long, 15 ft. wide and 39 in. deep.

The Panuco River is very low for six months every year, which does not permit navigation of large ships between El Higo and Panuco. In order to overcome this difficulty they have designed an all-welded barge which permits navigation in 27 in of water with a useful load of forty tons.

Fig. 1—Framework Completed

The boat was built upside down in order to facilitate welding of the bottom and then turned over to complete the covering. Both oxy-acetylene and arc welding were used in the construction. Some interesting photographs showing the framework inside of the boat and completed barge are shown above and on the opposite page.

Fig. 2—An Inside View

Fig. 3—Completed All Welded Barge

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SECTION ACTIVITIES

(CONTINUED FROM PAGE 4)

behalf of the Southern Pacific, and Frank Longo, Welding Supervisor, Southern Pacific Shops, acted as official guide through the shops. This was a very interesting visit and showed many and varied applications of welding.

NEW YORK

The regular monthly meeting of the New York Section was held on the 22nd of January. This was a joint meeting with the Metropolitan Section of the American Society of Mechanical Engineers. The subject of the meeting was "Fusion Welding of Unfired Pressure Vessels." This was a presentation and public discussion of the proposed specifications for the Fusion Welding of Unfired Pressure Vessels. C. W. Obert, Consulting Engineer, Union Carbide and Carbon Res. Labs., Inc., and Chairman, of the A.W.S. Conference Committee on Welding, acted as Chairman of this meeting.

The purposes of the proposed specifications were outlined by Mr. E. R. Fish, Chief Engineer of the Hartford Steam Boiler Inspection and Insurance Company; and Chairman, Sub-Committee on Unfired Pressure Vessels, A.S.M.E. The general discussion was led by Fred R. Low, Editor-emeritus *Power* and Chairman, Boiler Code Committee, A.S.M.E. The viewpoints of both the A.S.M.E. and the A.W.S. on the subject were presented by James Partington, American Locomotive Co., and Chairman of the A.S.M.E. Sub-Committee on Welding; and by E. H. Ewertz, Consulting Engineer, and Chairman of the Joint Pressure Vessel Committee, A.B.W.-A.S.M.E., respectively.

G. O. Carter, Consulting Engineer, The Linde Air Products Company, spoke on the Industrial Application of Welding to Pressure Vessels. Some interesting information was presented on X-ray testing, sound testing and other methods of non-destructive tests, by experts in that field.

NORTHERN NEW YORK

The next meeting scheduled for this section will be held on Feb. 6 at the General Electric Company, Schenectady. Dinner will be served at 6.30 in the General Electric restaurant. The meeting will be held at 8:00 p. m. in the Research Laboratory lecture hall. The speakers are to be H. T. Florence of the Cleveland Crane and Engineering Company and T. H. Booth of the Buffalo Forge Company.

PHILADELPHIA

The Jan. 19 meeting of the Philadelphia Section was on the subject of Pipe Welding. The first speaker of the evening gave a talk on "Welding of Distribution Pipe Lines" which was illustrated with lantern slides. The second speaker—W. R. Ost, Engineering Department, Air Reduction Sales Co., New York, delivered an address on "Improved Methods of Welding on Transmission Pipe Lines and Compressor Stations." His talk was also illustrated with lantern slides, together with an exhibit of some specimens of welds.

PITTSBURGH

Resistance Welding and Pressure Vessel Welding were discussed at the Dec. 17 meeting of this section. Over one hundred welding enthusiasts attended the meeting and listened to two very interesting papers on welding subjects of interest to many. The first paper was on Resistance Welding presented by H. A. Woofter, Chief Engineer and Vice-President of the Swift Electric Welder Company, Detroit. Mr. Woofter's paper was illustrated with approximately 100 slides which showed a diversified line of resistance welders designed to make all kinds of metal parts from ferrous and non-ferrous metals and from non-corrosive steels. He also showed many parts made by resistance welding.

The concluding paper was by P. R. Hawthorne, Consulting En-

gineer, Sharon, Pa., who talked on Welding Heavy Plates and Pressure Vessels. Mr. Hawthorne's paper touched on the importance of heat-treating welded vessels, why this should be done, the fundamental requirements to obtain good welds made on heavy plates and pointed out that a welded vessel could be subjected to greater stresses than a riveted vessel. He also discussed methods of testing and stated that if regulatory bodies continue to impose unreasonable restrictions in the manufacture of welded vessels that the advancement of welding in this particular field will be greatly retarded.

SAN FRANCISCO

The annual joint meeting with the American Society for Steel Treating was held on Jan. 19 at the Engineers' Club, San Francisco. Mr. C. A. Britton, Instructor of Welding at Oakland Central Trade School discussed some of the recent achievements of welding and the great future for welding.

George T. Kerr of Hall Scott Motor Co. spoke on the subject of "Electric Welding Aluminum."

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